COMMERCE, JUSTICE, SCIENCE, AND RELATED AGENCIES APPROPRIATIONS FOR 2010

HEARINGS

BEFORE A

SUBCOMMITTEE OF THE

COMMITTEE ON APPROPRIATIONS

HOUSE OF REPRESENTATIVES

ONE HUNDRED ELEVENTH CONGRESS

FIRST SESSION

SUBCOMMITTEE ON COMMERCE, JUSTICE, SCIENCE, AND RELATED AGENCIES

ALAN B. MOLLOHAN, West Virginia, *Chairman*

PATRICK J. KENNEDY, Rhode Island
CHAKA FATTAH, Pennsylvania
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C.A. "DUTCH" RUPPERSBERGER, Maryland
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NOTE: Under Committee Rules, Mr. Obey, as Chairman of the Full Committee, and Mr. Lewis, as Ranking Minority Member of the Full Committee, are authorized to sit as Members of all Subcommittees.

JOHN BLAZEY, DIXON BUTLER, ADRIENNE SIMONSON,
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Subcommittee Staff

PART 5

Printed for the use of the Committee on Appropriations

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COMMERCE, JUSTICE, SCIENCE, AND RELATED AGENCIES APPROPRIATIONS FOR 2010

TUESDAY, MARCH 3, 2009.

SCIENCE OVERVIEW

WITNESS

DR. RALPH CICERONE, PRESIDENT, NATIONAL ACADEMY OF SCIENCES

OPENING STATEMENT BY CHAIRMAN MOLLOHAN

Mr. MOLLOHAN. I am glad to see you made it in this cold morning. It was cold this morning. March comes in like a lion, goes out like a lamb. So we have spring to look forward to.

Welcome before the Commerce, Justice, Science, and Related Agencies Subcommittee. We appreciate your coming today to provide your perspective on the state of science in the United States and where you see it heading.

As those responsible for appropriations for four significant research agencies, NSF, NASA, NOAA, and NIST, we want to ensure that we provide appropriate support for science and technology so that our country can continue to enjoy economic growth beyond our growth in population.

We recognize that there is more to encouraging and sustaining a healthy science and engineering enterprise than government financial support. The freedom of inquiry offered by our democracy is significant as are patent protection and the rule of law.

Our responsibility is to balance the investment of federal tax dollars across many competing government programs and across the research and science and education activities included in our jurisdiction. Finding the right balance is crucial along with providing levels of support that are sustainable politically and practically.

Research is usually a long-term investment and is poorly served by boom-bust cycles in funding and employment.

The National Academy of Sciences of which, of course, you are currently President provided a major influential report entitled Rising Above the Gathering Storm that highlighted the critical need for increased funding for NSF, NIST and the DOE Office of Science and recommended increases have been provided especially in the just enacted "American Recovery and Reinvestment Act of 2009."

So, as the U.S. science enterprise is receiving increased funding, are we striking the right balance among different areas and agencies and between science and science technology, engineering, and mathematics education?

This morning's hearing is the first in a series that are intended to give this Subcommittee a clearer view of the state of science and science education in the U.S. and a basis on which to make the tough choices balancing federal investments in the research agencies within our jurisdiction.

Dr. Cicerone, we look forward to your starting us off with an overview of the state and direction of the U.S. science enterprise. Your written statement, of course, will be made a part of the record.

Before I ask you to begin, I would like to call upon our Ranking Member. This Subcommittee was extremely well served by the good work of our colleague Rodney Frelinghuysen last year who was the Ranking Member on this Committee. And we were sorry to see Rodney go, but we are very pleased to see Ranking Member and former Chairman of the Committee, Frank Wolf, join us back.

Frank has a deep understanding of the accounts that are under the jurisdiction of this Subcommittee and he is a great guy in every way and we are very pleased to have him here.

Frank.

Mr. WOLF. Well, thank you, Mr. Chairman. I am really pleased to be back with you. We had a great working relationship before and I really am glad to be here.

And I want to welcome the witness. And with that, I will just yield back. Thank you.

Mr. MOLLOHAN. Thank you.

Dr. Cicerone.

DR. CICERONE OPENING STATEMENT

Mr. CICERONE. Good morning and thank you, Chairman Mollohan and members of the Subcommittee.

My name is Ralph Cicerone. I am President of the National Academy of Sciences, which, as you know, was chartered in the middle of the Civil War, 1863, with the mission of advising the government on matters of science and technology.

So even though we are not part of the government, that is our job and we work along with the National Academy of Engineering and the Institute of Medicine.

I appreciate the opportunity to speak with you this morning about the enterprise of science in the United States because it is a subject that is enormously important to our country and, yet, complicated enough that I do not think anyone knows the whole picture. Therefore, I think the hearing that you are holding is essential for all of us.

With your permission, Mr. Chairman, I will just skip through parts of my testimony here and there.

Mr. MOLLOHAN. Go ahead.

Mr. CICERONE. Thank you. And submit it.

The enterprise of science in America today is very strong. Federal investment in American science has enabled the United States to be the world's scientific leader since World War II, and continuing federal investment has led to unmatched growth and prosperity through the creation of technology and technological advances themselves have increased the quality and span of life for Americans and for people around the world.

Our science has also led to amazing discoveries about our universe and about life itself and all together, it has contributed greatly to the high opinion in which the United States is held in most countries.

Other significant benefits include the strengthening of our military power to deter and to fight wars.

Science comes in many kinds and your Subcommittee oversees much of American physical sciences and engineering, yet there is also a major enterprise in biomedical science.

American science continues to lead the world in the physical sciences, but faltering federal support over the last 30 years or so along with increased emphasis and investment elsewhere in the world has reduced our lead.

In fact, our leadership is now disputed in some fields of physical science. In fundamental biology and biomedical science, including the creation and development of pharmaceuticals and biomedical instruments, the American lead is larger, although not in all subspecialties.

In other countries, there is increased attention to inventorying and measuring scientific investment and productivity, especially in nations where national plans are being implemented.

But besides federal funding, as you just said, Mr. Chairman, other ingredients are needed to sustain the science enterprise. Talented, ambitious people are essential, for example, and the stream of such people starts with childhood education and continues through college and university years to graduate and postgraduate education.

To attract the brightest graduates, career opportunities must also be available along with specialized equipment in laboratories and computers.

American science draws deeply from American-born people who study and produce here, but we have also enjoyed a large advantage over other nations through the immigration of students and scientists from other countries to our shores.

We received many gifted people who fled pre World War Europe and the Nazis followed by others who left iron curtain countries and still others who sought opportunities here from Britain, from all of Europe, Japan, China, India, and Africa, for example.

Names like Einstein, Fermi, Bethe, Von Braun, Von Neumann, and Eric Kandel come to mind. In fact, 24 percent of the living American Nobel Prize winners were born in other countries.

Similarly, of the scientists elected to membership in our National Academy of Sciences just in the last ten years, nearly the same number were foreign born, that is 23 percent, and are now naturalized U.S. citizens.

However, recognition as Nobel Laureates and as NAS members is usually for important research that took place 20 years ago or even earlier.

A more current indicator is that approximately 65 percent of all of our current doctoral engineering students in the United States are from foreign countries. This flow of human resources to the United States continues. But as we place more barriers against the entry of talented people and as more opportunities develop in their own home countries, we will not be able to rely on them as much as we have.

Research laboratories. American research universities are acknowledged to be worth imitating and many nations are trying to do so. The doctoral students who study and conduct research at our universities are extremely important to the science enterprise along with postdoctoral researchers and faculty members.

And our research universities and liberal arts colleges also provide opportunities for undergraduate students to experience research.

After World War II until roughly the end of the Cold War, American corporations also operated some amazingly distinctive and productive scientific research laboratories. Probably the apex was at Bell Laboratories where prodigious amounts of basic research were conducted.

Bell Lab scientific staff was star-studded. They won several Nobel Prizes. They published their own journals. They created many advanced products. They contributed to the national defense while they also created and maintained the world's best telephone system.

And there were other important corporate research labs such as at IBM, Xerox, Exxon, Chevron, and Eastman Kodak.

Now, today those same laboratories do very little basic research compared to earlier years. The major responsibility for conducting research now is with our universities. However, it is an advantage, I think, to combine research and graduate education.

So while our universities already have more than enough duties, the recently acquired burden of carrying the national research agenda fits well with the mission of education.

And our system of American national laboratories and research institutes also represents important capabilities.

I want to mention two other strategic advantages enjoyed by American research, philanthropy and business investment.

The American practice of philanthropy is not practiced widely anywhere else. Private funds from individuals and foundations provide essential support for our research and for student scholarships and fellowships.

And, of course, I mentioned business funds, but I will not go into detail today, about such funds invested in universities.

Science is also a source of good will for the United States. American achievements and activities in science have created a great deal of good will worldwide. Significant numbers of foreign leaders attended American colleges and university graduate schools before returning to their homelands and they remain lifelong friends.

There appear to be large opportunities for American science to become a major component of our diplomatic efforts while it also continues to undergird our economic and military strength.

Let me say a few words about science education. Chairman Mollohan already mentioned the report from the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine in 2007 called Rising Above the Gathering Storm. It arose from a 2005 request from your Senate colleagues and discussions with a number of House members, including Mr. Wolf, who is here today, who led any number of efforts in his home State and around the country about science technology and competitiveness.

The charge that that Committee accepted was to identify actions which federal policymakers could take to enhance the science and technology enterprise so that the United States can successfully compete, prosper, and be secure in the global community of this century.

The authoring Committee of 20 distinguished Americans placed a specially high priority on increasing America's talent pool by vastly improving K through 12 science and mathematics education. They argued that it is essential to produce more teachers who are well grounded in the sciences and mathematics themselves and to existing teachers to improve and maintain their science-content skills. And they proposed to use previously tested methods to achieve those goals.

The Gathering Storm report dealt with all levels of education all the way through graduate and postdoctoral levels. I hope that Mr. Augustine will discuss this topic further with you.

There are, of course, arguments about why American children do not stack up better than children of many other countries and maybe whether our standardized tests give too much emphasis to factual knowledge as opposed to reasoning ability, yet it remains that we receive very few visitors from around the world who want to learn about and to imitate our K through 12 system while we receive scores of foreign visitors to our university graduate schools who are trying to emulate them and to reproduce them worldwide.

We have much work to do to improve our K through 12 and college level science and math education. Not only do we want to increase the flow of human talent into high level science and research, we also want to fill the pipeline with science students so as to equip the nation's workforce to be able to create and manufacture products which take advantage of scientific breakthroughs.

And as Chairman Mollohan said, we need a scientifically literate population to comprise an electorate informed on many contemporary issues.

Finally, improved education enables individuals to launch their own productive careers.

The Gathering Storm report called attention to the importance of creating something like a new National Defense Education Act specifically to provide support to science and engineering graduate students.

Now, recently there are some reports from around the United States, informal reports, that applications to attend graduate science schools are up right now apparently because of reduced job prospects for baccalaureate degree holders in industries such as finance and investment.

It is especially important to provide support for these students not only to see them through their Master's and Ph.D. programs but also for research opportunities later.

Amongst these new and prospective grad students, the new ones, there is special interest in energy science and technology and in climate change.

For example, working in the science and technology of materials that might be useful in capturing solar energy and in storing solar and wind energy is very attractive now.

Similarly, plant science is appealing as we consider pathways towards advanced biofuels that would not decrease food production and emerging issues of food security are attracting interest.

And the science of climate change presents many fundamental and complex challenges that are perceived by young people very clearly who want to engage these challenges through science. So I think we have a special opportunity today supporting science.

The Rising Above the Gathering Storm report presented four main lines of action that the federal government should take to enhance the science and technology enterprise for the reasons stated and they are to vastly improve K through 12 science and math education, to increase federal support for science and engineering research, to attract the best and brightest to American higher education in science and engineering, and to create an environment for innovation through a combination of economic, legal, and immigration policies.

The report recommended special attention to increased federal investment in physical sciences, engineering, mathematics, and information sciences and to the Department of Defense basic research funding.

It focused importantly on energy science and technology research and somewhat on the National Science Foundation and the Department of Energy and that choice of emphasis was very wise.

However, the report omitted detailed discussion of NASA, NIST, and NOAA and, yet, the work of these agencies not only complements that of NSF, the National Institutes of Health and the Department of Energy, but these agencies are also important to address the new challenges I just mentioned, and to support American science and higher education and, frankly, to all that we must do.

The recently passed federal stimulus package has provided substantial support towards major national goals and goals that have been arrived at very thoughtfully. The stimulus bill funds aimed at American science, I believe, will be used very productively and in forward looking ways.

Let us hope and resolve to make these new levels of baseline for further advances.

Thank you once again for inviting me to appear before you, Mr. Chairman. I would be happy to address any questions that I can.

[Written statement by Ralph Cicerone, President of the National Academy of Sciences follows:]

Statement of

Ralph J. Cicerone
President
The National Academy of Sciences

before the

Subcommittee on Commerce, Justice, Science, and Related Agencies
Committee on Appropriations
U.S. House of Representatives

March 3, 2009

Good Morning Chairman Mollohan and members of the Subcommittee. I am Ralph Cicerone, President of the National Academy of Sciences, which was chartered by Congress in 1863 to advise the government on matters of science and technology. We work along with the National Academy of Engineering and the Institute of Medicine.

Thank you for the opportunity to speak with you today about the enterprise of science in the United States. It is a subject that is tremendously important to our country and complicated enough that no one knows the whole picture. Therefore, the hearing that you are holding is essential for all of us.

Current Status of American Science

The enterprise of science in America is very strong. Federal investment in American science has enabled the U.S. to be the world's scientific leader since WWII. Continuing federal investment has led to unmatched growth in prosperity through the creation of technology, and technological advances have increased the quality and span of life for Americans and for people around the world. Our science has also led to amazing discoveries about our universe and about life itself and altogether. It has also contributed greatly to the high opinion in which the United States is held in most countries. Other significant benefits include the strengthening of our military power to deter and to fight wars.

Science comes in many kinds. Your subcommittee oversees much of American physical sciences and engineering yet there is also a major enterprise in biomedical science.

American science continues to lead the world in the physical sciences but faltering federal support over the last 30 years or so, along with increased emphasis and investment elsewhere in the world, has reduced our lead. In fact, our leadership is now disputed in some fields of physical science. In fundamental biology and biomedical science including the creation and development of pharmaceuticals and biomedical instruments, the American lead is larger although not in all sub-specialties.

How can I say these things about our relative position? What measures does one use? There is no simple yardstick (meter stick) that does all of the measuring. Instead, we keep track of many variables like federal research spending, numbers of patents, numbers of research papers in top-notch scientific journals, citations to those papers, how many new Ph.D.'s are produced each year, graduate student enrollments, and Nobel Prizes and other prestigious prizes that are awarded on merit.

Actually, it is somewhat of an exaggeration to say that "we keep track" because not many people do; one of the best and only sources of information is the National Science Foundation and the National Science Board. In other countries, there is increased attention to inventorying and measuring scientific investment and productivity, especially in nations where national plans are being implemented.

Besides federal funding, what else is needed to sustain the science enterprise? Talented ambitious people are essential. The stream of such people starts with childhood education and continues through college and university years to graduate and postgraduate education. To attract the brightest graduates, career opportunities must be available along with specialized equipment such as laboratory instruments and computers.

American science draws deeply from American-born people who study and produce here but we have also enjoyed a large advantage over other nations through the emigration of students and scientists from other countries to our shores. We received many gifted people who fled pre-WWII Europe and the Nazis, followed by others who left Iron Curtain countries and still others who sought opportunities here, from Britain, all of Europe, Japan, China, India and Africa, for example. Names like Einstein, Fermi, Bethe, von Braun, von Neuman and Kandel come to mind. In fact, 24 % of living American Nobel Prize winners were born in other countries. Similarly, of the scientists elected to membership in the National Academy of Sciences in the last ten years, 23% were foreign-born (and are now naturalized U.S. citizens). However, recognition as Nobel Laureates and as NAS members is usually for important research from 20 years ago or longer. A more current indicator is that approximately 65% of all current doctoral engineering students in the U.S. are from foreign countries. This flow of human resources to the U.S. continues but as we place more barriers against the entry of talented people and as more opportunities develop in their home countries, we will not be able to rely on them as much as we have.

Another feature of science today is that international collaboration in scientific projects has become much more common. Such collaboration is desirable for several reasons and it is becoming more necessary for us in fields where we do not enjoy strong leadership positions.

Research Laboratories

American research universities are acknowledged to be worth imitating and many nations are trying to do so. While world rankings are not precise and are not even attempted often, it is widely believed that most of the best research universities are American. Students and researchers from around the world seek to enroll in, and affiliate with our campuses. The doctoral students who study and conduct research at our universities are extremely important to the science enterprise, along with postdoctoral researchers and faculty members. Our research universities and our liberal arts colleges also provide important opportunities for undergraduate students. Cooperative programs in which students enroll while also working for science and engineering companies, although not numerous, are very valuable as well.

After WWII until roughly the end of The Cold War, American corporations operated some amazingly distinctive and productive scientific research laboratories --- like those of Bell Labs where prodigious amounts of basic research were conducted. Bell Labs' scientific staff was star-studded and they won several Nobel Prizes, they published their own research journals, they created many advanced products and they contributed to the national defense, while also creating and maintaining the world's best telephone system. Other important research labs were at IBM, Xerox, Exxon, Chevron and Eastman Kodak.

Today, these corporate laboratories are still highly capable of developing new products (Intel, for example) and conducting superb applied research but they do very little basic research compared to earlier years. The major responsibility for conducting such research now is with our universities. It is an advantage, I believe, to combine research and graduate education so while our universities have more than enough responsibilities, the recently acquired burden of carrying the national research agenda fits well with the mission of education. And our system of American national laboratories and research institutes (some managed by universities) also represents important capabilities. It should be noted that research universities are also expected to serve as engines of regional economic growth.

American Philanthropy and Business Investments as Strategic Advantages

I want to mention two other strategic advantages enjoyed by American research. One is the American practice of philanthropy which is not practiced widely anywhere else. Private funds from individuals and foundations provide essential support for our research and for student scholarships and fellowships. Finally, American venture capital and other kinds of investment funds have contributed notably if irregularly to important scientific and technological developments.

Science as a Source of Good Will

American achievements and activities in science have created much good will worldwide. Significant numbers of foreign leaders attended American colleges and university graduate schools before returning to their homelands and they remain life-long friends.

A recent global public opinion survey found that admiration for U.S. science and technology remains nearly universal*. Another survey found that strong majorities of those surveyed in Morocco, Jordan, Lebanon and the United Arab Emirates have positive views about American science and technology. (2004 Arab American Institute/Zogby International Survey). There appear to be large opportunities for American science to become a major component of our diplomatic efforts while it also continues to undergird our economic and military strength.

Science Education.

In 2006, the National Academy of Sciences, the National Academy of Engineering and the Institute of Medicine produced a report called "Rising Above the Gathering Storm". It arose from a 2005 request from your Senate colleagues Lamar Alexander and Jeff Bingaman and discussions with Rep. Bart Gordon and other House members. The committee that authored the report was asked to identify actions which federal policymakers could take to enhance the science and technology enterprise so that the United States can successfully compete, prosper and be secure in the global community of the 21st century. The authoring committee of 20 distinguished Americans placed especially high priority on increasing America's talent pool by vastly improving K-12 science and mathematics education. They argued that it is essential to produce more teachers who are well-grounded in the sciences and mathematics themselves and to assist existing teachers to improve and maintain their science-content skills, and they proposed to use previously tested methods to achieve these goals.

The "Gathering Storm" report dealt with all levels of education through graduate and postdoctoral levels. While I trust that Mr. Norman Augustine will discuss this topic further, I want to emphasize how important it is to improve our K-12 science and math education. There are, of course, arguments about why American children do not stack up better than children of many other nations and whether the standardized tests give too much emphasis to factual knowledge as opposed to reasoning ability. Yet we receive few or no visitors from other countries who want to learn about and imitate our K-12 system while the movement to create foreign versions of our university graduate schools is large and intensive.

We have much work to do to improve our K-12 and college-level science and mathematics education. Not only do we want to increase the flow of human talent into high level science and research, we also want to fill the pipeline with science students so as to equip the nation's workforce to be able to create and manufacture products which take advantage of scientific breakthroughs. And we need a scientifically literate population to comprise an electorate informed on many contemporary issues. Finally, improved education enables individuals to launch productive careers.

The "Gathering Storm" report called attention to the importance of creating something like a new National Defense Education Act to provide support to science and engineering graduate students. There are some current reports from around the U.S. that applications to attend graduate science schools are up, apparently because of reduced job prospects for baccalaureate degree holders in industries including finance and investment. It is especially important to provide support for these students not only to see them through their Master's and Ph. D. programs but also for postdoctoral research opportunities later.

Amongst these new and prospective new graduate students there is special interest in energy science and technology and in climate change. For example, working in the science and technology of materials that might be useful in capturing solar energy and in storing solar and wind energy is very attractive now. Similarly, plant science is extremely appealing now as we consider pathways toward advanced biofuels that would not decrease food production. And the science of climate change presents many fundamental and complex challenges that are perceived by young people who want to engage these challenges through science.

Supporting Science Today – A Special Opportunity

Earlier I mentioned our report "Rising Above the Gathering Storm". It presented four main lines of actions that the federal government should take to enhance the science and technology enterprise so that the United States can successfully compete, prosper and be secure in the global community of the 21st century. They are: vastly improve K-12 science and math education, increase federal support for science and engineering research, attract the best and brightest to American higher education in science and engineering, and create an environment for innovation through a combination of economic, legal and immigration policies.

"Rising Above the Gathering Storm" recommended special attention to increased federal investment in physical sciences, engineering, mathematics and information sciences and to DOD basic research funding. It focused importantly on energy science and technology research and somewhat on the National Science Foundation and the Department of Energy. This choice of emphasis is extremely important as the events of 2006-2008 have shown once again.

Although "Rising Above the Gathering Storm" omitted detailed discussion of NASA, NIST and NOAA, the work of these agencies complements that of NSF, NIH and DOE and these agencies are very important to addressing these new challenges, to American science and higher education, and to all that we must do.

The recently passed federal stimulus package has provided substantial support toward major national goals that have been arrived at very thoughtfully. The stimulus-bill funds aimed at American science will be used very productively and in forward-looking ways, I believe. Let us hope and resolve to make these new levels a baseline for further advances.

Thank you for inviting me to testify. I would be happy to address any questions that the subcommittee has.

Footnote* "Global Public Opinion in the Bush Years (2001-2008)" <http://pewglobal.org/reports/pdf/263.pdf>http://pewglobal.org/reports/pdf/263.pdf , which was released on Dec. 18, 2008 by the Pew Global Attitudes.

SCIENCE FUNDING

Mr. MOLLOHAN. Doctor, thank you. Thank you for your testimony, and again, thank you for appearing here today.

I know the Subcommittee members have a lot of questions for you and very much value the opportunity to discuss these issues with you.

I will ask in the first round if we could stick to a five-minute questioning period and then the second round and that will give everybody an opportunity early on to ask questions and then in subsequent rounds, they can follow-up in more detail.

Doctor, given the current largely bipartisan commitment to increase funding for science, which we are already seeing and we are very pleased, I can tell you all members of this Subcommittee are very pleased to see an increased interest in larger funding for science, what do you feel should be the end point of this growth and when should we reach a stable level on investment in real terms?

Mr. CICERONE. Well, obviously that is a fair question, but I think we are so far away from that level that it is hard to say.

But to be more thoughtful, I think we have to think about what our goals are for American science. A little over 15 years ago, we did a study at the Academy on basically how much science was enough, that is pretty much your question.

And the conclusions of that group were that there are certainly several major goals for science: to maintain a basis for economic activity, to help to defend the national security, emerging issues of the environment, and, in some cases, to lead the world in important social and cultural issues.

They concluded that it is going to be increasingly difficult for the United States to lead in all fields and that thought had to be given to which fields we absolutely felt it essential to lead such as those involving economic development.

But the second category is in those fields where we could no longer be the clear leader, to be good enough to recognize breakthroughs that happened anywhere else in the world. So, for example, high temperature superconductivity was basically discovered in Switzerland and the new breakthroughs had been shown there, but our physicists and material scientists were close enough to the lead that they could instantly recognize the breakthrough and move into that area of work.

So as we try to answer that question, when can we stabilize after these increases, I think we have to have goals of how many fields do we really want to lead the world in and in how many other fields are we content to follow, but to try to follow closely enough to be able to recognize major breakthroughs.

I do not have a number in mind. It is just too far in the distance to be able to see when we will be at a stable level.

Mr. MOLLOHAN. Well, we are looking for numbers here.

Mr. CICERONE. All right.

Mr. MOLLOHAN. I do not know. Maybe in terms of factors or something and what does the recent funding in the stimulus package do for you and what is sustainable as you look forward and how do you compare the increases, for example, at the National Institutes of Health with regard to the increases in the accounts under our jurisdiction?

Mr. CICERONE. There are certainly some lessons there that we can try to learn about what happened after the National Institutes of Health had a doubling of their budget and how they got into the pickle now where they are oversubscribed again under level funding.

The success rate of investigators going through competitions for grants is frightfully low. It is something like 18 percent right now.

Mr. MOLLOHAN. We would like to avoid that as we look to the future and increased funding in these accounts.

Mr. CICERONE. My understanding is it is going to take a combination of management at the agencies as well as thoughtful budget foresight so that the number of long-term commitments that are made with these new funds does not exceed the funding that is likely to be in place for the next two, three, four years. That is one issue.

But to try to get to a number of what we actually need, I would look at the backlog that has developed in various fields, for example, at the National Science Foundation and the other agencies of how many proposals that had been submitted into these competitions or given the highest marks and then not funded over the years.

We understand that a lot of the stimulus funding is going to be used to clear up some of the current year's backlog and from them to move back into a situation where maybe at least a third of the funding proposals could be funded.

So that would suggest at NSF not only just a 50 percent increase in the funding, but because the grant sizes have gotten so small, we have people who do not even apply anymore because they cannot get enough done with an NSF grant. So clearly at NSF the doubling that has been requested by the Rising Above the Gathering Storm report would be kind of a minimal baseline.

Where we go from there would depend on how much of a backlog develops and the proposal pressure of highly competitive proposals, some of which are facilities and equipment also.

Mr. MOLLOHAN. Mr. Wolf.

STEM GRANTS

Mr. WOLF. Thank you, Mr. Chairman.

I would hope that we could do much more than we are currently doing. And Jim Cooper and I have a bill which tries to deal with this whole spending entitlement issue where we put more in math and science and physics and chemistry and biology.

And when I get on the train in Washington and take it to New York, if you just close your book and look to the right and to the left, the factories are in decay, the windows are broken, the graffiti is all over, and we just do not seem to be making things anymore.

There is that sign over the bridge in Trenton that said Trenton makes and the world takes. And Trenton does not make anything anymore. Trenton is a city that has been impacted. It has gang problems.

And I really think we are having a tough time. One of the reasons, I think, is that young people are not as interested as they used to be. I saw figures, and maybe you will have the answers, showing that of the STEM grants last year, only 50 percent of them were taken up.

Do you know if that is true or not?

Mr. CICERONE. No, sir, I do not.

Mr. WOLF. Can you check or maybe we can check.

Secondly, how many students do we have majoring in math and science and physics and chemistry and biology compared to, say, the Chinese and also India? Do you know that number?

[The information follows:]

Congressman Wolf asked about full utilization of STEM grant resources by students. The funds are known as Academic Competitiveness and SMART grants, and are overseen by the Department of Education.

Created by Congress in 2006, the Academic Competitiveness and SMART Grant programs were designed to encourage students to take rigorous courses in high-school and to major in science, technology, engineering, or mathematics (the STEM fields), or a language deemed critical to national-security needs. Both programs were identified by Congress as a supplement to Pell grants for eligible students. Students must maintain at least a 3.0 GPA in college to be eligible.

In 2006/2007 $428M was given out of $790M available. In 07/08, $493M was given out of $850M available. An overview of both programs and a table of state-by-state student awards for each grant program can be found in the following PDF prepared by the Department of Education: *http://www.ed.gov/programs/smart/results2007/national.pdf*

It is likely that underutilization of SMART and Academic Competitiveness grants was not due to disinterest. Instead, the above-listed report indicates a lack of knowledge on the part of students and their parents about these resources. There is not a separate application necessary for each of these grant programs, but one does have to indicate on the FAFSA application about student eligibility. It is likely that students (and their parents) are not aware of these relatively new grant programs and do not understand what they are about or terms for eligibility.

The Department of Education has been criticized (see Chronicle of Higher Education article—*http://chronicle.com/daily/2009/01/9471n.htm)* for not exhibiting more effort in publicizing these programs. Also, undergraduate colleges have registered complaints as to the difficulty of identifying and confirming student eligibility for these awards. In other words, startup flaws in the system appear to be working against strong program interest as well as institutional encouragement of student participation in seeking awards.

I do not know what resources are designated in the 2009 budget for these programs or what has happened to unused funds from earlier years.

Again, the underutilization of these grant funds do not point to a lack of interest in STEM careers, but instead to a lack of interest or understanding among students, parents, and undergraduate institutions about these two grant programs. Program-reporting regulations could be acting as a deterrent as well. The use of funds from these programs has incrementally increased over the last two funding cycles, but not at the speed which Members of the Congress would have hoped.

Mr. CICERONE. I know that the fraction of our students who take college degrees, who major in the sciences and math is, I believe, it is about five percent. I can check that. And it is a fraction of that in China and India. It is probably less than half of that.

[The information follows:]

ANSWERS: The total number of bachelor's degrees (in all fields) awarded in China has grown rapidly in recent years, and is roughly comparable to the number awarded in the United States. Bachelor's degrees in math, natural sciences (e.g. physics. biology, chemistry), and engineering as a percentage of total degrees is much higher in China (about 50%) than in the United States (about 15%). Thus, China's annual production of bachelor's degrees in these fields is roughly 2.5 times that of the United States (over 600,000 for China, under 250,000 for the United States). Views differ with regard to the quality of those degrees. With no comparable standardized testing, the anecdotal information from company leaders hiring in both countries is that there is a significant quality gap between the U.S. and Chinese cohorts.

Reliable statistics on Indian higher education degrees are not available, given the mix of public universities, private universities, and unaccredited private universities all providing engineering degrees. Recent research on engineering and IT-relating bachelor's degrees indicates that for 2005–2006, U.S. production of such degrees stood at about 129,000, with India's production about 220,000, and China's about 575,000.

With regard to foreign students in the U.S., in recent years, temporary foreign residents have not constituted a high percentage of recipients of U.S. bachelor's degrees in math, natural science, and engineering. U.S. citizens and permanent residents, who would be expected to stay in the United States after earning their degrees, made up 95% of degree recipients in those fields. In fields such as computer science and engineering, the percentage of temporary foreign residents rises to 7 or 8 percent.

There are some interesting data on foreign students who receive Ph.D. degrees in science and engineering in the U.S. These data generally show that 60% to 70% of these new Ph.D. degree holders are still in the U.S. two to five years after receiving their degrees, and that students from China and India stay at above-average rates.

Data and Sources:

United States data are for the year 2005. Total bachelor's degrees: 1,437,200; Total math, natural science, and engineering bachelor's degrees: 235,619; Proportion of math, natural science, and engineering bachelor's degrees: 16%.

U.S. citizens and permanent residents earning math, natural science, and engineering bachelor's degrees: 223,255; Proportion of U.S. citizens and permanent residents among math, natural science, and engineering bachelor's degrees: 95% (though temporary residents earn up to 7% or 8% of engineering and computer science bachelor's degrees)

Stay Rates for Ph.D. degree holders: Computing Research Association (*www.cra.org*) and S&T Indicators at NSF).

China data are for the year 2004. Total bachelor's degrees: 1,196,290; Total math, natural science, and engineering bachelor's degrees: 610,705; Proportion of math, natural science, and engineering bachelor's degrees: 51%

India: Reliable statistics on Indian higher education degrees are not available (see NSF S&E Indicators). Gereffi et al. have produced an estimate of "engineering" bachelor's degree production that includes computer science and other IT-related degrees with the following results for 2005–2006: United States, 129,000; India, 220,000; China, 575,000.

Notes:

a. Social and behavioral sciences excluded

b. U.S. and China figures are for first university degrees (ISCED 5A)

Sources: S&E Indicators 2008, Appendix Tables 2–28 and 2–38 *http://www.nsf.gov/statistics/seind08/c2/c2s4.htm*

Gary Gereffi, Vivek Wadhwa, Ben Rissing, and Ryan Ong. 2008. Getting the Numbers Right: International Engineering Education in the United States, China, and India. Journal of Engineering Education. January.

Mr. WOLF. In overall raw numbers, how do we compare? The reason I ask, and I do not know if it is true, I saw that India and China last year had 700,000 students in engineering. We had 70,000.

And then it went on to say that 40 percent of our students were foreign students who were probably not going to stay here. And is that figure accurate? And how long, if it is accurate, how long can you kind of go on with those numbers?

Mr. CICERONE. The figure, I think, is probably exaggerated for China and India because it includes people who are not taking, let us say, as strong a degree as we would have in four years, but who are getting much more practical technician type training, two and three year programs.

I am not sure anybody has the exact number, but it is not grossly exaggerated. I would say that is on the high side and it is growing so fast that if it is not that big now, it will be soon.

Mr. WOLF. Could you see if you could get those numbers for the Committee.

I also saw that we have fewer physicists, Ph.D. physicists in the country today than we had in 1956 before Sputnik. Is that accurate?

Mr. CICERONE. These figures have all come out since the Gathering Storm report.

Mr. WOLF. Are they accurate though? Is that an accurate figure?

Mr. CICERONE. It is approximate, but I think we actually— that number also has been criticized in the last year with some evidence that we have a few more physicists now than we did in the mid 1950s, but not a lot.

Mr. WOLF. Well, if you can correct the numbers, but also just a few more would sort of be a failure because the population in the country today versus then is fairly dramatic.

What do you think we should do to have young people get interested? What age do you believe do we lose them? You very seldom hear somebody who goes to the University of California, University of Virginia, majors in history and then in their sophomore year transfers into biophysics.

[The information follows:]

Before listing any numbers about physicists in the United States now and in 1959, please note that the total population of the U.S. has increased by about 70% in those 50 years.

The number of physicists is only an estimate, because many physicists take jobs not identified as a "physics position," and in other cases, people who do not have degrees in physics may fill positions labeled as such. That said, the American Institute of Physics (AIP) has a membership (combined number from its constituent societies) of about 125,000 at last count. That number includes people with physics degrees at the BS, MS, and PhD levels. It is known that about 27% of people awarded the BS degree in physics go on to get a PhD. Of those 34,000 PhDs awarded over the years, only about 40% are in teaching or university research positions in physics. That number of 14,000 active PhD physicists is the same as the number cited in the Department of Labor Bureau of Labor Statistics. According to the AIP, there are 9,150 tenured or tenure-track university positions in physics in 2006 (contract with 8,450 in 1996); the remainder of the 14,000 are in non-tenure-track positions.

The number of Ph.D. degrees awarded annually in physics in the United States was in the range of 500–600 around the time of Sputnik. In recent decades, the number has fluctuated in the 1,100–1,500 range. However, the proportion of bachelor's degrees in physics to total degrees awarded was twice as high in the year before Sputnik as in 2004.

Physics Ph.D.s awarded—Sourc: American Institute of Physics *http://www.aip.org/statistics/trends/highlite/ed/figure13.htm*

Physics Bachelor's Degrees as a Percentage of the Total—Source: APS News, August/September 2007 *http://www.aps.org/publications/apsnews/200708/physicsbachelors.cfm*

Mr. CICERONE. That is right.

Mr. WOLF. Usually they go into engineering or math or science and then into business or something else. I am not saying nobody ever does it, but there are probably not a lot of people.

What age do you believe we lose them? Is it fifth grade, third grade? Have there been any studies showing that?

Mr. CICERONE. It seems every time someone looks, it seems to be earlier and earlier. That is, the children seem to have a lot of curiosity, interest, and excitement about nature and science when they are young and as they get older, it seems that whatever we are doing to them, we are losing more.

But I think the biggest break point is probably seventh grade or eighth grade. It has to do with Algebra, the teaching of Algebra, and the way children respond to Algebra word problems and then

Algebra I and Algebra II. We seem to lose an enormous number of children there. They develop some kind of an antipathy toward science and math and it is hard to get them back after that.

Mr. WOLF. Is the Academy looking at anything? How do you maintain and keep people? You are?

Mr. CICERONE. Yes.

Mr. WOLF. Could you share with us what?

Mr. CICERONE. Mostly I would say these are local programs all around the country who are working towards increasing the flow of students through high school into college science technology and math programs. And they find the same experience. For example, if the child is excited about biology.

I remember a lot of programs in California I worked with, we found that the failure rate had to do with first and second year chemistry, among the students who wanted to be biologists. And that failure in turn was based on the calculus and physical chemistry which in turn revealed a weakness all the way back to that seventh and eighth grade Algebra.

So getting the math skills strong through high school has been identified as one of the keys because with strong math skills, then these young men and women can go on to do almost anything, whether it is engineering or whether it is economics or physics.

So a lot of focus has been on working on the math skills. The other focus is to have teachers who are comfortable doing experiments with children which really bring out the curiosity and that is where so much emphasis, as I think you know, Mr. Wolf, has focused on equipping teachers and finding new teachers who are really comfortable in the content matter, that is who are not just generalists, but who have, if they are going to teach physics, a decent background in physics, if they are going to teach biology, a decent background in biology.

But we have a long way to go. I think in California, two-thirds of the high school biology teachers do not have a degree in biology just as an example. So we have a long way to go.

Mr. WOLF. Last question.

Mr. CICERONE. More weaknesses than we do the solutions.

Mr. WOLF. Well, then that leads to the last question and it is a difficult question. But since you do not work for the Administration, you can be very candid and tell us what you really believe. And I think you would carry a lot of weight.

If you had to look at where we are on math and science and physics, chemistry and biology and all of these and the nation with regard to science, would you say that we are doing very well, would you say that we are holding steady, or would you say that we are in decline?

Think carefully because I think——

Mr. CICERONE. I would say we are in decline, but it is split. Our top end students can and do compete with the best anywhere. Our weakness is with a great bulk of the population who are not attaining a minimal level of understanding. So if we are content with a country based on the achievements of the highest few, we can hold steady. But we are not educating the great bulk of our students well enough.

So when you go to our really top schools and see what the students are doing, they are doing wonderful things and better all the time and they can compete with anybody. There just are not enough of them and that is why we depend so much still on foreign students coming here because we are not producing enough engineers, we are not producing enough scientists, but our best students are as good as anywhere in the world, if not better. There just are not enough of them. We are not doing enough with our entire population, so that is why I would say we are in decline.

Mr. WOLF. Okay. Thank you for your time.

Thank you, Mr. Chairman.

SCIENCE EDUCATION

Mr. MOLLOHAN. You are not doing enough farming to identify and nurturing? A lot of the population is being lost in the schools?

Mr. CICERONE. Yes, sir.

Mr. MOLLOHAN. We are just not producing the students?

Mr. CICERONE. Yes, sir. Our best continue to hold their own with anybody, but we are not bringing along the rest of the people enough.

Mr. MOLLOHAN. Mr. Honda.

Mr. HONDA. Thank you, Mr. Chairman, and welcome.

Just to pursue the line of questioning that Mr. Wolf had asked, in your opinion then, we are talking about changes in the field of education and the funding and support.

Given the recent infusion of revenue and the direction that we are going in and the areas that we are concentrating on now, where are those differences compared to the last few years and is it more or less in terms of funding and support in those areas that relate to research and science and technology?

Mr. CICERONE. Do you mean, sir, with reference to the stimulus accounts?

Mr. HONDA. Whatever revenues we are looking at now, whether it is stimulus or the current Omnibus bills that we are looking at, the type of support and the amount of support in the areas that are necessary.

Mr. CICERONE. Probably the most dramatic change has been in the general field of research and development in energy. Our federal expenditures for energy R and D stagnated over the last 30 years and probably went down in constant dollars. I am pretty sure they did.

And this stimulus bill that has just been approved has a great deal of emphasis on energy. That is probably the most outstanding example of change overnight where we really have not done anywhere near what is necessary on energy research in this country.

Since the oil shocks of 1973, 1974, and 1979, and a little bit of work around 1980, things have just gone downhill until this past year.

Mr. HONDA. In terms of educational policy, preschool to postgraduate, and looking at creating an inclusionary kind of a policy so that we expect all youngsters to be able to understand math and science as individual citizens, not necessarily to be scientists, but to be thoughtful and critical consumers, how would you address and where would you make those changes in terms of making those kinds of shifts in the way we are doing things or do we need to do it?

Mr. CICERONE. Probably every one of us has their own ideas.

First of all, a disadvantage we have is we do not have a national system of K through 12 education. It is all controlled locally so that even those of you with tremendous responsibility for the federal government cannot do everything for K through 12 education, but you can set examples and that those of us who have seen progress with our children, our own communities always have stories to tell about exemplary people who come forward and can work with children on their own terms, showing them interesting curiosities, ways to make a career, practical issues like how you can live your life better by understanding how this works or knowing how to do these kinds of calculations.

There does not seem to be any substitute yet for individual attention to children. So we continue to depend enormously on the teachers and, of course, the family home life. I wish I could be more insightful than that, but I think that is the answer.

Mr. HONDA. So individual attention that is consistent across the country on instruction and how we address these areas is something that would or should be looked at?

Mr. CICERONE. With examples from successful people who the children have heard of.

Mr. HONDA. Okay. And that is different from standardized assessment.

Mr. CICERONE. Well, we have to have some kind of assessment, though, to know whether we are just feeling good or whether we are actually achieving anything.

Mr. HONDA. But if we have standardized assessment with an inconsistent feel of treatment, then the assessment is always going to be not where you want it. Is that accurate? So our focus should be really on trying to figure out how we address across the country consistent curricula and instructional activities to the child, individual child is what I hear.

Mr. CICERONE. Yes. But some kind of nationalized standards are also necessary so that we do not kid ourselves in our own communities that we are like a little bit better than average.

Mr. HONDA. But this national treatment and approach to each youngster, that is going to be important, I mean that we are consistent across the board. And I guess we call it equity of instruction and resources. Rather than trying to victimize a victim, we have set them up so that we need to really provide the wherewithal for them to all be able to meet their potential.

Mr. CICERONE. Of course.

Mr. HONDA. Okay. Thank you.

Do I have a little bit more time, Mr. Chairman?

Mr. MOLLOHAN. Your first round is up.

Mr. HONDA. Yes, sir.

Mr. MOLLOHAN. You will get a second one.

Mr. Bonner.

Mr. BONNER. Thank you, Mr. Chairman.

Doctor, I would like to go back to a question that Mr. Wolf posed and try to get you to enlighten us or at least enlighten this member.

He asked a question that I was going to ask, and that is what we are doing to try to reach down to the right age and the right grade to capture the minds of young people to develop future scientists.

Can you tell us what country or countries should be the example because it seems to me that the teaching of math or science or physics or chemistry, that the subject would be the same even if it is in a different language in China or in Japan or wherever, but obviously some other countries are doing a better job than we are? Which ones should we look to?

Mr. CICERONE. Other countries are doing a better job of creating a floor level where nobody falls below. I do not think they are doing a better job at the high end. In fact, there is some evidence that if it is just teaching things to be remembered and kind of wrote learning, other countries do better than us. But on reasoning skills and thinking skills, there is a lot of evidence that we still do as well as we should.

I think the real challenge is for us to work against our own best selves, that is we know we can do better. And these comparisons with other countries can always be criticized.

For example, I just saw an article in Science Magazine last week that showed me that on reasoning skills and any number of tests, American students across the board are doing as well as many of their international counterparts. They are just not mastering as much material. They are not working as hard.

But in terms of creativity, the reasoning skills are very, very important. So I am not willing to say that we are failing against all other countries. I think we have to focus on just lifting ourselves and as perhaps Representative Honda mentioned working with the potential of every child rather than trying to compare ourselves to Finland or Japan or Germany. There is a lot of disagreement on that point.

Mr. BONNER. Well, my hometown of Mobile is the host of the State School for Math and Science, High School for Math and Science for our entire State of Alabama. I am very supportive of their efforts. I have actually sought earmarks for them.

I guess the question, I am not going to ask you to say what are the top two or three schools for math and science in the nation, but when they come to me asking for help for computer technology or a new library, what should the very best schools that are training future scientists and mathematicians, should they be looking to make sure as a part of their curriculum so that they could one day be considered one of the best?

Mr. CICERONE. So it sounds like that school identifies perhaps the children who have some kind of a gift or extra curiosity. There are few of these around the country and they are remarkable. And to provide opportunities for students like that is just absolutely essential because we just cannot ignore them.

I would focus on the teachers. All the evidence is the quality of the teacher is the most important thing, the ability of the teacher to lead the children and to respond to unusual questions from children in a reasoning way rather than trying to give them flat out yes or no answers, but to lead them through deeper and deeper considerations and better and better experiments.

So that falls on the teacher. I would focus on the teacher. And if the teachers say they need those kinds of equipment, I would listen to them.

SCIENCE FUNDING

Mr. BONNER. And I guess my last question is this, that clearly this Subcommittee and many members of Congress do support increasing the funding for human sciences and, yet, everywhere we turn, the American people have a great angst about what is going on with their country. I mean, the stock market has certainly taken a tumble the last several weeks. People have seen their savings disappear. Costs go up, perhaps taxes going up.

So I think a fair question on behalf of the American taxpayer is, and the Chairman alluded to it in his question, but to not pin you down to a specific number, what can we tell the American taxpayers that the benefits of increased support for the sciences will get them, because there are two things that I think most people believe we will never see and that is peace in the Middle East and a cure for cancer? And, yet, science may not provide the first. It certainly could play a role in providing the second.

I guess my question is, what is the last most significant breakthrough in the sciences that we could tell the people back in my district or any other district in America that is so significant that it was worth the investment of more of their hard earned tax dollars?

Mr. CICERONE. We have a whole string of those. I am not sure I could say the last one chronologically, but all around us, we have the benefits of this research like the global positioning system and everything it has done for our safety and traffic routing.

And it all came out of discoveries that had nothing to do with the final product. People in laboratories were working with lasers and masers and timing devices, all of which turned out to be essential for the global positioning system.

Going back a few years before that, these clunky devices that were individual transistors about as big as this microphone. When they were invented at Bell Laboratories and other places, nobody foresaw that they could be shrunk and made faster and embodied in automobiles to get better fuel efficiency and in biomedical devices to not only record data but to detect any unusual behavior with the biomedical sensing device.

The nuclear magnetic resonance devices that give us NMR diagnostics now in medicine not only for sports injuries but for imaging of various organs and circulatory system and brain function, none of these were invented. That is, they were done because research was getting done and students asked questions and their supervisors asked them questions about how things work. And then some entrepreneurial person came forward and said, you know, I could make something useful out of that.

So we have a whole string of these discoveries and, yet, it is hard to fit this into an elevator when somebody asks you why are you supporting all this extra spending at a time like this. It is very hard for us to predict what is going to happen six months from now.

But I think our reasons for science have even expanded beyond what they were 15 years ago where we were focusing on military strength and economic strength in the post Cold War world. Now we know that we have national security issues developing out of climate change. We have some world leadership issues that people are looking to the United States because of the fondness they have for us and they like to see us leading.

We know that some of our science serves that purpose from a diplomatic point of view. But, once again, it is hard to say to somebody your tax bill just went up because we want to support more science. I feel that way myself, but I am happy to pay the taxes.

Mr. BONNER. Thank you, Mr. Chairman.

Mr. MOLLOHAN. Thank you.

Mr. Schiff.

ENERGY RESEARCH

Mr. SCHIFF. Thank you, Mr. Chairman.

Doctor, I wanted to follow-up on your comments regarding energy which I was delighted to hear. I think we did make a very important and sizeable investment in energy research in the stimulus bill.

Just a few days ago, I visited a brilliant constituent of mine named Bill Gross who runs Idea Lab in Pasadena, which is a high-tech incubator. And one of the solar companies that has spun off from Idea Lab will be completing in May a solar power plant in Lancaster, California that for the first time will produce energy, will produce electricity from solar power at a price cheaper than deriving it from natural gas.

They use a combination of affixing the solar panels on to units that track the sun to maximize the efficiency as well as mirrors to concentrate the sunlight and not have to go to so much expense in the production of the panels.

So this will bring the price point down below natural gas, which is remarkable. It is hard for me to see how if that can be done this will not take off like a rocket.

So I am very optimistic. I think we are on the cusp of a paradigm shift in energy, but how quickly that happens, I think, will depend also on how sensibly we incentivize and encourage that to continue and develop new science in this area and as well as encourage the transition of that science into technology and industry.

So what I want to ask you is, what are your thoughts on what is the next step that we should be taking? We put a lot of funding in the stimulus bill. What steps can we take to further our work, the development of good science and technology in the field of energy?

Mr. CICERONE. If I am not mistaken, the development you are talking about near Lancaster is actually focusing the sunlight to use the heat to make electricity on a fluid rather than the conversion directly into electricity.

Mr. SCHIFF. Right.

Mr. CICERONE. And it is turning out to be remarkably successful without even using a lot of great new basic science, but a lot of small improvements focused into one. It is fantastic.

Well, as you know from California's history with electricity, the fact that Californians only use about 60 percent as much electricity per capita as the rest of the country does, it has taken a lot of work in California not only in science and technology but in public policy.

The pricing strategies whereby the utilities have been given incentive to provide energy services along with just raw electricity, the pricing strategies that allow the companies to charge more at times of peak usage have encouraged conservation which then save capital funds to help to keep the cost down. All of these things have to be done in tandem.

But the challenge in front of us is huge. We are working on a set of reports right now which I am hopeful is going to help, it is called America's Energy Future, where we are looking at, this at the Academy, where are we getting our energy now, how much does it cost in each case, what are the prospects in the next few years, including efficiency improvements, and then trying to identify the barriers towards further improvement.

And the barriers turn out to be a combination of science, technology, public policy, incentives, as you said. So we have a challenge to work together over a period of years to get all this done for a wider adoption of solar and wind energy and even nuclear. It is not going to be easy, but the incentives are huge.

The strategic challenge is probably to create fleets of electric drive vehicles that can run off of the electricity generated from renewable and nuclear sources as opposed to using petroleum. That would accomplish a great deal for this country, but it is a strategic challenge because right now if you had the electricity, you do not have the cars. So it is going to have to go hand in hand.

ORBITING CARBON OBSERVATORY

Mr. SCHIFF. I look forward to that report.

Let me ask you one other very quick question if I could. The Orbiting Carbon Observatory, a lot of the research on climate change and in particular on this project comes out of the Jet Propulsion Lab, my neck of the woods. As you know, the launcher failed to place that mission in orbit. This is a heartbreak for all of us.

As you look at our climate change research portfolio, do you see the data that this would have gathered as irreplaceable? Should we build another satellite to take its place? What do you recommend?

Mr. CICERONE. Well, that mission, it is just a tragedy that it failed. I think it was February 23rd, because we were expecting several kinds of information from it. The only instrument like it is one that the Japanese just launched in December or January. And I am not sure which instrument would have turned out to be better. They are somewhat different.

But the Orbiting Carbon Observatory was supposed to do at least two things. One is to track the carbon dioxide ebbs and flows and the bulges here and there that come out of both natural sources of carbon dioxide as well as industrial ones, and then also see the deficits, that is where is the carbon dioxide disappearing into the world's green things and the oceans to be able to do a better accounting for scientific purposes so we can make better predictions of future climate change.

The other thing that that satellite possibly could have done is contributed to the United States' ability to monitor any new international agreements that might be reached in the future. That is, if the countries of the world sign up and say I am doing X, Y, and Z, what would be our ability to independently monitor whether country X is doing what it is supposed to be doing and whether or not the agreements are being effective.

We were hopeful that OCO as it was called would give us some national ability which in turn could be shared with other countries to monitor international agreements, but we will never know now.

So I think a strong case can be made that that instrument should be rebuilt and launched as quickly as possible. Usually producing the follow-on version of an original instrument, the prototype, is cheaper than the first one, but I do not know the details on this one.

It was really the creation of the Jet Propulsion Laboratory and people out there would have to give the answers.

Mr. SCHIFF. Thank you, Mr. Chairman.

SATELLITES

Mr. CICERONE. On that line, I think of the 20 satellite instruments we have looking at the earth right now, 19 of them are passed their lifetime. We expect to see these instruments going dead and if not falling out of the sky and that includes some weather satellites that we all depend on every day as well as these longer term issues. We have a real problem with our fleet of satellites.

Mr. SCHIFF. Thank you, Mr. Chairman.

Mr. MOLLOHAN. You have 19 reaching or already beyond——

Mr. CICERONE. I think it was at the close of 2008, it was either 19 out of 20 or 20 out of 21 satellite borne instruments looking at the earth have gone past their predicted lifetime. They are not fresh anymore.

In some cases, it is pretty black and white, clear cut. That is, if an instrument had a certain amount of cryogenic fluid on board because it had to cool the detectors, we knew how fast that would evaporate and we knew that the lifetime, that would be it.

In other cases, the instruments are continuing to perc along. They are not dependent on, you know, a certain amount of fluid and they will keep working. We do not know how long.

Mr. MOLLOHAN. Mr. Culberson.

SCIENCE FUNDING

Mr. CULBERSON. Thank you, Mr. Chairman.

Dr. Cicerone, I cannot tell you how much I admire the National Academy of Sciences, National Science Foundation. The work that you do is so important. And for the future prosperity of the nation, thrilled to be a part of this Subcommittee and work with the Chairman, members who are all equally committed to supporting the National Science Foundation and your work. It really is a privilege to work with you guys on this.

I am particularly and wanted to focus, Dr. Cicerone, on how the Congress funds the sciences and what your recommendations would be in order to give greater stability and predictability to science funding.

It is my impression after serving on the Committee for a number of years and following the work of science grants and I have been a subscriber of the Journal of Nature and Science for about 20 years and try to read as much as I can. I am an amateur astronomer, very passionate about the space program and funding the sciences.

Mr. Wolf's question is so important and to have you testify that in your opinion we are in decline, and I think that is self-evident to all us, profoundly disturbing.

The National Academy of Sciences chartered in 1863 to advise Congress.

Do you have any thoughts or recommendations, number one, so we give you an open-ended opportunity to tell us? What in your opinion could we do or should we be thinking about doing to restructure the way that the Congress appropriates funding for the National Science Foundation, NIST, the National Institutes of Health?

But let us start first with NSF because bouncing around from year to year is terribly destructive and damaging to the ability of undergraduates, for you to attract graduate students, for example, to stay in these grant programs.

What do you recommend that we need to do to give more stability and predictability to science funding year after year?

Mr. CICERONE. Well, you have already said some very important things and that is the commitment to the goals and to help people, including your own constituents, understand how important these goals are.

The National Science Foundation is perhaps one of the jewels of the world and you can see it the way other countries are always trying to imitate it.

The NSF standards are seen as the goal standard in terms of competition. The competition for NSF funding is extreme, sometimes brutal.

Mr. CULBERSON. Yes, sir.

Mr. CICERONE. The success rates when people send their best work to the National Science Foundation and seek funding, the success rates are now about 22 percent. And it is kind of like an unemployment statistic. When the unemployment figures go up, you know that you have got problems because a lot of people have dropped out and are not even applying anymore.

Mr. CULBERSON. Right.

Mr. CICERONE. We have got problems like that at NSF now that people are not even sending in applications because they are so discouraged.

Mr. CULBERSON. Well, they do not know what next year's numbers are going to look like.

And looking at other countries based on your experience over the years, do you have any recommendations today that you could talk to us verbally about and then follow-up with a written response? Very important.

What should Congress do to change the way we fund the sciences to ensure great stability, predictability, a steady growth over a number of years to give those scientists in the field the assurance that their grant is not going to be jerked out from underneath of them in the second or third year?

[The information follows:]

To produce and maintain a strong core of scientist and engineer researchers in the United States, we must teach and encourage young men and women who are now in our K–12 schools and in colleges and then provide support for their counterparts who are in graduate schools and those with new doctoral degrees. A great start would be to implement fully the recommendations in our 2007 report Rising Above the Gathering Storm: stronger investment in cutting-edge research, fostering a new generation of dedicated researchers, building a K–12 education with a strong STEM element, improving the environment for business innovation in science and technology areas.

The US research universities are still the best in the world, the most innovative in both research and the innovativeness of the people produced. The gap between us and other parts of the world is narrowing. We were preeminent; we are not probably best among equals. We must increase and maintain our commitment to developing and supporting talented people. Students can sense opportunities and also the lack of opportunities, partly by watching older, more experienced people in their own fields of interest. When students see accomplished and motivated older researchers who are not able to obtain research funding, the younger students can get discouraged.

A key issue in science funding is that the competitive grants programs at NSF and NASA, for example, must be robust enough and stable enough to offer opportunities for truly worthy proposal requests to be funded. Now, the fraction of successful applications is only 22 or 23% at NSF and the grant sizes are too small to support even modest-sized projects. In fact, some researchers do not even apply any more because of these low chances for success and small grant sizes. At the NIH, grant sizes are much larger but success rates are even lower, perhaps 19%. My opinion is that success rates must reach at least 33 to 35% and that grants must be at least twice as large as they are now, and that competitive grants for major pieces of scientific equipment are also needed.

We need ways to establish believable, stable career opportunities for young scientists in areas of critical national need (as NIH has done for biomedicine) as the only way to build a best-of-class technical workforce in these areas. The US is the unquestioned world leader in biomedical research. As we increase such research funding, however, we must avoid bust-to-boom-to-bust cycles. Management of the allocation of funds in coordination with management of anticipated budgets is required; lessons from recent increases at NIH followed by periods of stagnation and cuts can offer lessons.

Broader goals are to re-energize longer-term, truly innovative research (more emphasis on truly innovative ideas, longer grants, critical mass in funding) to contribute to job creation and solutions to national problems. Peer review has served America very well in science funding but many reviewers are too reluctant to support researchers whose goals are large; reviewers often favor incremental progress.

Similarly, it is essential to develop financial/career incentives to attract good scientists/engineers (especially women and minorities) into K–12/college teaching as the fastest way to increase the quality of teachers, and now is a great time to do it since there are talented, committed people without choice jobs.

Mr. CICERONE. Well, a few of you are in such leadership positions that I am sure that you do a great job in making the case and, yet, I think it would help if the public, more of the public understood why you were doing that.

So in the case of NSF, the reason it is so special is that the NSF does not have the kind of mission, say, that NOAA does where NOAA has to run the weather service and the fisheries service which in turn are very important.

NSF was created basically to respond to the scientific and engineering community when people had good ideas which did not yet fit into one of the national missions like fisheries or the weather service. So NSF is kind of the bright spot.

Mr. CULBERSON. Yes, sir. I understand. Forgive me. We have got such a brief time.

Mr. CICERONE. Sorry.

Mr. CULBERSON. And I will follow-up. You are very kind, Mr. Chairman. Thank you.

I am really driving at and what I am trying to get you to help us do is give us your best ideas on how, I mean, really restructure.

Personally in my opinion, we ought to have an independent board of scientists that recommend a budget number to us, Mr. Chairman, that is independent of the President's budget no matter who the President is and that we fund that level of science based on the best advice of the best experts in the field and we get politics out of the way and let the peer reviewed competitive grant process drive the work.

Please tell us what your best recommendation is on how in your opinion we should change the way we fund science in the future so that it is more stable, predictable, and we have a growth curve that will give the assurance to the scientific community and the world that the Chinese are not going to produce ten engineers to every or ten engineers or scientists to every one of ours.

Mr. MOLLOHAN. Along those lines, if the gentleman will yield.

Mr. CULBERSON. Yes. Please, Mr. Chairman.

Mr. MOLLOHAN. In your closing remarks, you indicate let us hope and resolve to make these new levels, referencing the stimulus, a baseline for further advancement.

STIMULUS PACKAGE FUNDING

Mr. CICERONE. Well, the reason I say that is I am thinking ahead now to what Representative Culberson was just hinting at. If you put together a group of people whose judgment was strong and that you trusted, what they would be looking at is what kind of demand, what kind of capability do we have.

So the stimulus package is going largely into meeting the unfunded top proposals that were ranked in the top line by NSF and the other agencies just in the past couple of years.

You want to at least meet that level, and then the question is, can it continue and what is the mix of equipments and facilities and computers and people in the future. One way to keep track of that is the influx of highly competitive proposals.

Now, at NSF, far too small a fraction of those are being funded and the size of the grants that are being given out is far too small. They have fallen far down from historic levels that could have been maintained and should have been maintained.

I also read Science and Nature every week and the last issue I looked at from the week before last, the first nine papers were from—eight of them were from foreign countries and the ninth one had an American collaborator on it. That is what we are looking at in the physical sciences and engineering. We are in decline competitively.

We probably cannot afford to be the best in all fields. We are going to have to decide which fields we really have to be the best at and go for those and then the other fields be good enough to recognize breakthroughs elsewhere.

So the way to measure that would be to get these success rates back up at NIH and NSF, back up maybe to the one-third level at least.

Mr. CULBERSON. Well, let me say in conclusion, the Chairman has been very generous with his time. I would like to work with you, Mr. Chairman, and members of the Subcommittee to find a way to make that $3 billion one-time shot in the arm a permanent increase in the baseline for NSF and then really think creatively outside the box about what do we do to ensure that we do not bounce around like this in years to come because that is one of the most destructive, certainly, would you not agree, it is destructive and damaging to the grants that you award for the numbers to, funding levels to bounce around from year to year without any predictability or stability?

Mr. CICERONE. It is. And that creates the kind of management and leadership issue that you were talking about, how you can have the people in charge of the agencies working with the budget people to smooth things out instead of going through these boom and bust cycles.

Mr. CULBERSON. I have really appreciated your time, Mr. Chairman.

And I also want to say, Dr. Cicerone, we have not met before, but, and my colleagues know this, I am pleased to say I just earned another hundred percent perfect conservative rating from the American Conservative Union and my starting answer is no to almost all appropriations requests unless it is for the National Science Foundation, the NIH, or NASA.

Mr. CICERONE. Yes, sir.

Mr. CULBERSON. Your success, the success of America is contingent on the success of the National Science Foundation I am convinced.

Thank you, Mr. Chairman.

AMERICA COMPETES' AGENDA

Mr. MOLLOHAN. I thank the gentleman.

Following up a little bit on Mr. Culberson's line of questioning, NSF, NIST, DOE Office of Science, do you feel that beyond these agencies, do other agencies need significant increases? Should other agencies be a part of the America Competes' agenda? And, if not, why not? And if you could just discuss that.

Mr. CICERONE. I think there are the same kinds of needs elsewhere. For example, at the U.S. Department of Agriculture. There are emerging issues of food security, possibilities in plant biology butted up against the realities of climate change that are going to require more research than USDA has ever done. And I think a lot of it is going to have to be done more competitively than they have done before.

It is going to have to involve research institutes and universities all over the country and not just at the agriculturally favored places.

NASA, did you mention NASA, Mr. Chairman?

Mr. MOLLOHAN. Well, NASA and NOAA are under our jurisdiction. It is very interesting actually when we think about it in the context of climate change—the Department of Agriculture. I mean, I can see where they are very huge players in that arena.

But we are obviously particularly interested in NASA and NOAA in regard to that question.

Mr. CICERONE. And in the National Institutes of Health, there are a lot of indicators now that the capabilities that could be exploited are out there for the taking. We have got to encourage not only the young people but the established researchers who have been working for a long time to stay involved.

And they are running up against funding difficulties now. Their success rates have lowered. The avenues they have to explore not only in basic biology but in a number of disease related specific issues are larger than the finances can provide for.

The Department of Energy with its new leadership of Steven Chu, I think, is capable of doing a lot more than it has ever done before.

Mr. MOLLOHAN. Well, let me ask you.

Mr. CICERONE. And on the NASA side, they have more missions now than they did 40 years ago. NASA seems to be trying to do too many missions without enough funding. And the missions that have developed, I will give you two kind of polar opposites in the last 20 or 30 years.

NASA has become a force in our whole research and higher education infrastructure around this country that I am not sure the NASA Administration understands how important the graduate students and postdoctoral people supported by NASA have become in this country.

And it is not just about manned exploration. In fact, I am not so sure that the American public wants to stick with a decade or a multi-decadal commitment to manned exploration. Maybe they do.

But NASA's importance in astrophysics and astronomy is just fantastic these days. In earth observing and in climate change, so much of what we have learned about sea level rise properly averaged over the whole earth, not just one ocean basin, but now properly averaged, the observation of global precipitation, what is happening to the ice cover and the ice amounts, the mass, the horizontal extent, the thickness of the ice over the Arctic and Antarctic would not have happened without those satellites.

So these are all kind of new missions for NASA that have not been provided for.

Mr. MOLLOHAN. Well, it sounds to me like you are making an argument for NASA being treated as is NSF or NIST or the DOE Office of Science with regard to our competitiveness agenda that NASA science——

Mr. CICERONE. I think so.

Mr. MOLLOHAN [continuing]. Should be in the doubling and we should be in the business of trying to double NASA science as well as the other agencies.

Mr. CICERONE. I think so. Frankly, I think it was an omission of our report Rising Above the Gathering Storm. We did not talk enough about NASA and NIST in that report nor even the Department of Defense basic research was not given enough play in that report. That report was written awfully quickly.

But if you look at the impact on the American research enterprise, NASA is right in there.

Mr. MOLLOHAN. Well, pointedly, is it your testimony that you think that NASA science ought to be treated the same as those agencies that are enjoying a doubling agenda?

Mr. CICERONE. I think that NASA science should, yes. But the NASA science is not that large a part of the whole budget. So perhaps it is doable.

Mr. MOLLOHAN. I am not asking whether it is doable necessarily. I mean, that is another question. I am asking what is your opinion about what should happen.

Mr. CICERONE. I am just trying to distinguish between the entire NASA budget and the NASA science where I think you can make a case that it is just as important to the country as these other agencies.

Mr. MOLLOHAN. Do you make that case here today?

Mr. CICERONE. Yes.

Mr. MOLLOHAN. Okay. Thank you.

What about NOAA in those same terms?

Mr. CICERONE. NOAA has much less to do with universities than some of the other agencies and, yet, what NOAA does is essential on the climate and weather side and the fisheries side. They actually provide services on which a lot of our commerce depends and it has to be done with first rate science. They have some amazing laboratories internal to NOAA.

The impact on universities is not as evident except that it is places for people to go after they have finished at universities who then serve the rest of us. So I am very, very high on NOAA. I hope that the new administrator is confirmed quickly because she is dynamite. She has very high standards. You want to be on her side. She gets things done.

Mr. MOLLOHAN. Are there accounts within NOAA that you think should be treated in the same way and with the same goals as NSF and NIST with regard to a doubling of the funding?

CLIMATE CHANGE

Mr. CICERONE. I think the fleet of observing satellites for weather and climate is in real trouble with NOAA. That needs some quick attention and some serious attention. And there fortunately, I think most people understand how important they are because they see their TV shows about weather and they can figure out that it is coming from the National Weather Service and NOAA.

On the climate side, it is even worse. We do not even have an appropriate national strategy for monitoring climate. We have been doing it a piece at a time. And the faster things change and the more we have learned, we really need a strategy more than ever and NOAA should be in the center of that observing the oceans. And the problem with ocean acidification as part of climate change has not even been taken into account yet.

Mr. MOLLOHAN. My sense is that this Administration is beginning to give a lot of attention to climate, to climate study, climate change, and that NOAA is at the center of that as you just mentioned.

Can you tell us what you know about what is going on in the scientific community, what their attitudes are with regard to climate change, what responsibilities NOAA should be assuming with regard to that, and talk about it also in terms of funding?

Mr. CICERONE. We assume a mixed portfolio which has been the case in this country for climate work over the years. The National Science Foundation, NASA, and NOAA and to some extent the Department of Energy have been the leaders with contributions from places like Agriculture, Interior, but the four big ones have been NASA, NOAA, NSF, and Department of Energy.

And it has always been assumed that they work together. Each one of them brings something. But in terms of a national strategy, we really have a lot of catching up to do. The way things are unfolding and the premium put on the value of this information is very high now, partly as a national security issue, I might add. A number of reports from retired military people have made this plain in the last couple of years.

Mr. MOLLOHAN. This what plain?

Mr. CICERONE. The value of recognizing climate change as an element in national security and, therefore, getting the information that we need, how fast are things happening, where do we expect them to happen, and how much extra stress are they going to put on different countries.

Mr. MOLLOHAN. Well, looking at NOAA's responsibilities, it seems to me that that is a natural. And I understand there was a lot of discussion about NOAA's increasing responsibilities with regard to climate change.

Mr. CICERONE. But they cannot do it without NASA and NSF. They absolutely cannot.

Mr. MOLLOHAN. Oh, no, of course not. But I guess you are talking about all these needs. How does that get pulled together and what are the funding, as you look at them, what are the funding requirements for those respective agencies that are going to have increased responsibilities with regard to climate change?

Mr. CICERONE. I do not know what fraction of NOAA's total budget can or should go into climate because they have all of these other requirements on them at the same time, fisheries and weather service and so forth.

But NOAA has been central certainly during the Bush Administration. All the way back to the early 1980s, NOAA has been central to our climate program and, yet, so many of the contributions have been due to NSF and NASA contributions that it is hard to separate them.

Mr. MOLLOHAN. No. I understand what you are saying. You may not be prepared to talk about it and being able to dice it out like that.

Mr. Wolf.

Mr. WOLF. Thank you, Mr. Chairman.

I saw a film. I looked at it the other day. You ought to get a copy. I will try to get a copy for you. It is called IOUSA and Pete Peterson funded it.

I think in the year 2030, there is nothing left, there is not one dime for anything else other than the entitlements and interest on the debt, nothing for cancer research, nothing for education, nothing for the sciences.

And so the reality, this Congress is broken. This place does not work. And, I mean, just the other day, it took away tuition tax credits for young kids in the inner city who are trying to break out of the public schools, and I had a daughter who taught in the D.C. schools, trying to break out to get in where they can get a good education. And they are taken away from them.

And so, you know, there is that Simon and Garfunkle song, The Boxer. You ever hear it? You know, man hears what he wants to hear and disregards the rest. We are really only hearing what we really want to hear.

And so the sciences are going to be squeezed unless we can get some sense of kind of bringing this thing back. And so I really am not that optimistic because, frankly, every time this Congress does something, if the Republicans do something, the DCCC puts out a press release attacking them. If the Democrats do something, the Republican Campaign Committee puts out something attacking them. And pretty soon nobody does anything.

And so really we can talk about how important we want to get these numbers up, but unless we come together and develop a mechanism, and now I am not speaking as a Congressman, I am speaking as a father and a grandfather, we are in serious, serious trouble.

And so we can talk about how we have to spend, but how are we really going to do it? George Washington said deed is not just words and we need the deeds to demonstrate.

And let me say for the record the Bush Administration did not do a good job in the science area. I said it when I was Chairman and I will say it here for the record. But the Congress has to not just criticize, but has to come up with how we are going to deal with this spending in so many other areas.

Now, my staff pulled the report that I talked about. It was the Chronology of Higher Education. It said new grants for students fail to meet expectations. In the program's first, this is the STEM grants, academic, competitive, and national smart grant programs, in the programs for the first twelve months, the Department awarded roughly 430 million in grants, a far cry from the 790 million that lawmakers had appropriated for them based on the Department's projections. Some 361,000 students received the award, significantly fewer than the 505,000 the Department had estimated.

So I think we need to do something to make sure that young people have this interest. And I guess the question I want to ask you is, it is very tough to sort of answer your question about having people who have experience. We have a robotic program in a high school in our area. Thomas Jefferson has another one.

Should we not have more companies like Rockwell and Raytheon to give their top people to say one day or a half a day in the classroom so you are bringing people from SAIC or Raytheon or Lockheed Martin to really be coming in with practical hands-on experience that can kind of electrify, and I do not mean just twelfth graders, I mean fifth graders and sixth graders, and is much happening? Do you have any ideas about how we can do it and is it a good idea or what can we do to do that?

Mr. CICERONE. Well, I think it is a great case because science and technology really have so much to offer. I think we have seen it now in a couple of ways.

One is all the economists who have looked at the growth of the American economy, as Chairman Mollohan said, growth that surpasses the rate of population growth is where the surplus is generated.

Every one of them, regardless of their political position on the spectrum, has concluded that the science and technology efforts in the United States have accounted for at least half of the economic growth in the last 50 or 60 years. So we know that intellectually.

We also know from the debacle in the finance industry that is occurring that it is going to be pretty hard to run an economy based on a service industry, whether it is financial services, whether it is just tourism. We have got to get back to creating things and we are not going to be able to create things competitively with many other countries because of our labor costs, the standard of living we are all accustomed to.

So what we are left with is the innovation agenda that you know so much about, Mr. Wolf. It is creating a whole population which is not only capable of innovating but working in industries which have not been created yet. And that gets all the way back to high school. You are absolutely right.

So what I am hoping for is that the agenda is so positive in the first place that people can see it all. They know that individual opportunities depend on it and they know that our national future depends on it.

We all have to dig into our own communities and take advantage of those companies that will let their people go out and do a day's work like that or volunteer work in the evenings, retired people, and then creating a new cadre of teachers who are better equipped, the things that are going on, for example, out in Texas, the UTeach Program, that is being——

Mr. MOLLOHAN. What is that called?

Mr. CICERONE. It is called UTeach, capital U capital T, U–T and then each after it, at Austin. They have created a way that their science schools on the campus are equipping young people who are getting science degrees to be certified teachers with just about six months extra instead of a year and a half or two extra in school and financial support to help them using the school district, using private philanthropy, using companies.

And now California is imitating them. The University of California is imitating the UTeach Program. And several of the UC campuses are now turning out hundreds of new teachers who are certified. They are not emergency certified. They are certified to teach and they also have degrees in physics and chemistry and mathematics.

So this is a start and it is the states doing things on their own. I think they are going to be imitated in the other big states.

Mr. WOLF. Okay. Well, thank you.

Maybe, Mr. Chairman, we ought to ask the new Secretary of Education to come before the Committee. He has a great reputation. I have a daughter in education. She says people in education are very high on it. Maybe we should ask him to come and ask if he can lay out what they plan on doing, particularly with regard to the science, math and science and physics and chemistry and them.

The last issue, I think we need targets because if you do not have targets, I mean, if you are trying to run the mile, you have got to know where you ought to be at every time and you ought to have targets.

And I think what President Kennedy did on saying we were going to put a man on the moon was very, very positive. And I think the more we have targets so that we understand that we are either making those targets or we are falling behind, I think, is very helpful.

I heard and I am going to ask NASA this, but I had heard that China may very well beat us back to the moon. Is that accurate that China could or will or potentially may beat us back to the moon and do you think that is very significant or do you think it is just an interesting story? What does this mean?

But, one, have you heard that they may beat us back to the moon?

Mr. CICERONE. Yes.

Mr. WOLF. Yes. And what is the likelihood of that? Is it like one in a hundred or is it like they get a 50/50 shot at it?

Mr. CICERONE. I would not bet against it. Of course, it partly depends on what we do. On the other hand, I would not be too worried about it.

That could be an example of expensive programs where international cooperation is the way to get the job done, but also to minimize our own cost. There are lots of things that we have talked about today at NSF and NASA and NOAA that could be done cooperatively with other countries. For example, high energy physics.

It would be nice to have some of the experiments here in the United States, but at least the Americans can use the new facilities that are being built in Europe. Certain space programs like Exploration could be done cooperatively.

Where we have trouble is like with that instrument that Mr. Schiff mentioned, the orbiting carbon observatory. If we demand that we work with international cooperation on every space instrument, we are going to end up with needlessly complicated things instead of focused, targeted, cheaper things.

But going back to the moon could be a goal that we could cooperate with other countries rather than turning NASA upside down trying to do it ourselves for unknown purposes. I would not be too upset if the Chinese went there themselves, but it would be nice if we could cooperate.

Mr. WOLF. Of course, the problem with the Chinese, they are spying against us and they are stealing our secrets. And maybe that is not the best country to cooperate with. But they have about 30 Catholic Bishops in jail. They have a couple hundred Protestant Pastors in jail. They have plundered Tibet. They are persecuting the Muslims and they are killing people in prison and taking their blood type and selling the organs for $50,000. And they have stripped the computers of 17 congressional offices and other committees.

So they may not be the one that we want to cooperate with, but I think you make a good case about cooperation.

I have other questions, but I just think, you know, I will just thank you for your testimony. I urge you to really be bold and speak out and even be controversial in the sense because when people get within the Administration, the previous science advisor would never say very, very much and we just could not get him to say very much. And pretty soon, if you will not say very much what you really believe, why even ask you any questions because whatever you are going to get is not really the reality.

So I think that since your salary is not paid for, in essence you are not a government employee, we need people like you and Norm Augustine and others to be very bold, to speak out, obviously in a very kind way. We are not attacking and criticizing people, but just say here is where America is. And I think your credibility is probably greater, particularly since you are not in government than if you were.

So I would urge you, the Academy, and others like you to speak out, write editorials, do op-ed pages of pieces for the Washington Post and the Wall Street Journal and others to sort of let America know really where we are at this time.

And any thoughts you may have, and I am going to give you this——

Mr. CICERONE. Please.

Mr. WOLF [continuing]. If you could take a look at it, on what we do with regard to this because when we do talk about funding, here is the funding that laid on the table.

Mr. CICERONE. IOUSA?

Mr. WOLF. I am going to get you a copy. I am going to get you a copy. If you can have somebody come by, I will burn a copy off for you and get it for you by tomorrow.

But also if you could just look into this STEM Grant thing, any thoughts you may have as to why so much money laid on the table.

Mr. Chairman, thank you very much.

Mr. MOLLOHAN. Will the gentleman yield?

Mr. WOLF. Yes, I would be glad to yield.

INTERNATIONAL COOPERATION

Mr. MOLLOHAN. I just want to follow-up on the gentleman's question about international cooperation since you raised the question and Dr. Cicerone spoke to it.

There are a lot of scientific undertakings that are done through international cooperation. I would like for you to elaborate on Mr. Wolf's question.

And how does that relate to our maintaining leadership in science and technology? Where is it appropriate to consider international cooperation and where not? And what about the issue of locating major scientific facilities in the United States or offshore?

Mr. CICERONE. These questions are really more important than ever before. For example, in the physical sciences, we have heard a lot about the progress in China and India and Korea and, yet, the people who are probably beating us right now are Europeans.

In many fields of physical sciences, they would still like to see our leadership, but they do not need it. They are quite willing to move ahead with big facilities without us. They would like to see us cooperating on, for example, high energy physics experiments, but other fields of physical sciences too.

So it is these changes that bring those questions really up front. What can we do to advance the science to make sure that Americans are going to be part of it to enjoy their share of the discoveries and to including the ones that are going to have economic benefits when so much is being done elsewhere that we can no longer be in the lead in all fields? It is a new world. We cannot do it. I am being told this from everywhere I go.

Mr. WOLF. Mr. Chairman, could I just follow-up on that then.

Somebody from NSF who I will not say about two years ago said that Europe had a formal program of coming over here to encourage our engineers to go over. Like somebody would come and say, well, you are a German or you are Czech, come on back and work in your homeland for a couple years and you can go back.

Is there a formal program? Are the Europeans coming over to take our engineers or was that just a story?

Mr. CICERONE. I do not know if it is a formal program, but it is certainly happening. It is happening for a lot of reasons.

One of the papers this morning talks about a young woman Russian Ph.D. working at MIT who cannot get her Visa extended to stay on and work with MIT in the company she has been working with. She is going to go back.

A colleague of mine at Harvard I have known for many, many years, three of his last four Ph.D. students have gone to work in England and Germany instead of staying here.

We are hearing more when we quiz entering graduate students, do you want to go back to your home country when you are finished or do you want to stay here. This is a question that the National Science Foundation has been asking graduate students off and on for about 25 years. There is more of a tilt now towards going back home because they have got opportunities like they never had before.

But the United States still inspires people. People still, I think, would rather live in the United States. We have so much going for us that I think we can counter these trends by creating and maintaining the opportunities of the type you are talking about.

But the international experiments, the international collaborations are here to stay and we are going to have to be strategic as to how we advance certain fields. For example, the international nuclear fusion experiments that are now being done in France instead of the United States.

I certainly do not know whether that was the right thing to do, but it was a way for the United States to keep a hand in a kind of energy research that might pay off 30 or 40 years from now. Unfortunately, that is what people have been saying for 30 or 40 years already.

But it is so expensive that it seemed like the only way the United States could stay involved was to cooperate with several other countries, the so-called ITER Program, I-T-E-R, in France. There are going to be more decisions like that we are going to have to face. Can we go it alone or do we have to throw in with someone else and can we do some of them here instead of having them all going on overseas?

Those are the questions we are looking at now, especially in the physical sciences.

Mr. MOLLOHAN. We will follow-up.

Mr. Honda.

Mr. HONDA. Thank you, Mr. Chair.

The last 45 minutes are pretty thoughtful and stimulating. The idea of having guaranteed funding for the sciences with a growth factor, of course, plus asking you to be honest and critical of the way we are doing this, I think, has food for thought because there is an old Chinese saying, be careful what you ask for. But I think that those are thought provoking things.

The other comment you made earlier about India and China versus the United States, one of the things I have been telling my colleagues and just thinking about it is that when we use numbers, round numbers, but we are thinking specifically certain kinds of disciplines, we send the wrong message, I think.

And I think what I heard you say was that there are all kinds of disciplines in science and technology whether it is in India, China, or here and that the system that we have makes a big difference in how we grow our youngsters from the different countries.

And I think I heard you say that one of the things that we might want to look at is exercising more rigor in our instruction at the lower level. Higher education appears to be more desirable to imitate and I think that is because we filter through our system those that continue to go through our system where it encourages creativity and innovation and thinking outside the box. And I think that is the attraction that other countries when their cream of the crop starts to look at "where can I go."

Through this discussion I heard, we might want to think about co-signing letters to the Administration about lifting some of the administrative barriers that we have on immigration so that we can provide this free flow of students and professors so that we do not lose out on that because I think in the long run, we do lose out. And the attraction of being here is still very strong.

So we have some non-issues as far as this Committee is concerned, but I think there are some activities that we should be engaged in.

On the issues around NASA and NOAA and NIST and the other agencies, they are scattered throughout different departments with different funding sources, but they are all integrated and necessary to work together so that we have comprehensive information.

And given this atmosphere of wanting to look at stuff now, what would you recommend on how we could have NOAA and NASA and the other entities work together so that the outcome we will have is tools and technology and the knowledge and information that will be helpful for us to move forward in providing information on innovation, instruction, instructional strategies and innovation and having information on how to monitor and tell ourselves and give ourselves check points or touch points on controlling global warming?

Mr. CICERONE. Did you say controlling——

Mr. HONDA. Understanding it better, monitor ourselves so that we can say, you know, we are off on this area and we need to pull in because my sense is that we have these ideas about combating global warming with talking about carbon sequestration, but, you know, I am not sure whether we are thinking about also how do we monitor that, how do we quantify it and allocate that to certain countries or activities.

Mr. CICERONE. That particular task that you mention we have not given enough thought to yet and here we are on the verge of international agreements without probably a strategy for how we are going to monitor the agreements. That has to be done quickly. It is actually something we are working on behind the scenes now.

But coordinating across these agencies, I remember some outstanding examples from the mid 1980s where the administrator of NASA, the administrator of NOAA and the director of NSF worked together, actually went to the Office of Management and Budget and suggested that their budgets be co-examined along the lines of what was called the United States Global Change Research Program.

By starting at the very highest levels and by seeking co-examination of their budget packages, they sent a message to everybody that they were working together. And some of the things that flowed from that were to the benefit of everybody, including keeping the budget cost down.

For example, instead of developing new satellite sensors, NOAA depended on NASA with the high tech capabilities in the NASA centers and NASA scientists and engineers to develop new concepts for and new packages for satellite instruments which can be very expensive.

Now, I do not know whether they coordinated with the NRO or not because in those days, the National Reconnaissance Office was classified. The fact that it existed was classified. It was not very well known.

But the point is they coordinated so that NASA developed the new capabilities and then NOAA used them in an operational sense and delivered the data in a very effective way that never would have happened if either one of them had worked alone.

And then NSF was providing a lot of the intellectual raw material from universities, people who were working with all of those payloads and the mathematical models, the mathematical calculations, the data evaluations. And I think the fact that they agreed to go through OMB together helped.

That was one example of how coordination can still happen. So getting people like the agency heads together along certain lines of national priority can work.

Mr. HONDA. Perhaps that is something that we might want to think about in terms of some sort of an administrative policy and practice so that these things do happen. We can eliminate duplications. We can encourage collaboration and communication so that the interagency interactions, there will be less friction or barriers in that. You know, we encourage that.

And I would hope that that is something that we will move towards because I do not know that we can afford to be that loose with our money since we are really tight.

Mr. CICERONE. That is right.

Mr. HONDA. But that sounds like a good suggestion.

Mr. CICERONE. It is also true that we need all kinds. Just when you think you've got a perfect organization, somebody comes in from left field with a great idea that nobody thought of. And that is where NSF comes through again and again and again. They do not have these operational responsibilities, but they bring people in from all over who just come up with fascinating and fabulously important new ideas.

Mr. HONDA. How would you take all this new information that comes up so quickly and convert that into instruction for K–12 or——

Mr. CICERONE. That is especially hard, especially because we do not have this national system like I mentioned earlier. So much of our K through 12 education happens in every small locality. That is where the federal government can still set good examples.

For example, each of the agencies that Chairman Mollohan mentioned, I believe, has its own educational components too. NOAA, for example, and NASA have fairly substantial efforts to work with K through 12 education around the country. They support programs that provide materials based on, for example, that wonderful wall hanging here that is actually real results from remote sensing instruments.

These agencies provide educational materials to schools all over the country and summer workshops for teachers to enable them to work with those materials and, in some cases, some summer research opportunities for teachers.

So the federal agencies can do things like that which in turn then seed activities out in school districts all around the country using really modern things like that.

Mr. HONDA. Rather than impose on ourselves, then we should look at maybe the Department of Education which could take on that responsibility of gleaning the information from all the other different agencies and making some sense into that and providing that from the federal level.

Mr. CICERONE. My sense is the Department of Education is very good at distribution, but it would be perhaps wise to have the agencies with the real expertise in content matter provide the materials.

Mr. HONDA. And then your discussion on UT, that sounds like a good linkage also.

Mr. CICERONE. I think it is fabulous from what I can see.

Mr. HONDA. Thank you, Doctor. I appreciate that.

Mr. MOLLOHAN. Thank you, Mr. Honda.

Mr. Culberson.

Mr. CULBERSON. Thank you, Mr. Chairman.

I as a Texan can provide the Subcommittee with more information on the UTeach Program. It is an innovation of the State Legislature I think there and I came out of the Texas House, so I will be happy to provide that.

Mr. HONDA. And California has no problem copying Texas.

Mr. CULBERSON. What is one of the great things about this Subcommittee, Dr. Cicerone, is we are all truly on the same wavelength when it comes to the sciences.

And I would like to volunteer, Mr. Chairman, to, if I could, come up with a draft idea on changes to law in the way that the recommended budget numbers come to this Committee from an independent panel of experts.

I would like to work something out that we can circulate to think about making sure that there is a stable, predictable growing funding level for the National Science Foundation into the future because it is a real source of concern.

Dr. Cicerone, I would really like to have your help and guidance on that because it is why Congress chartered you guys back in 1863 to advise the Congress.

I once had and in thinking about designing this, if I could leave you with some good advice, someone, I think it was actually a City Council member once pointed out to me in Houston that the City Council makes decisions that will affect you next week and next month. The State Legislature makes decisions that will affect you next year. And the Congress makes decisions that will affect you for the next generation and generations to come.

So in a very real sense, we really have an obligation, this Subcommittee, the whole Congress to think about the next 10, 15, 20 years. We always do, but it is especially important now following up on Mr. Wolf's quite accurate point, it is an irrefutable fact that we are headed towards a path today that if we do not change, we are going to become like Argentina.

The Comptroller of the United States said that by the year 2020, the safest investment in the history of the world, U.S. treasury bonds, could very well be graded as junk bonds. That is just 11 years away.

And as Mr. Wolf says, we are going to spend every dollar we take in by 2030 on the social programs.

So really this becomes even more important, Mr. Chairman, that we find a way to wall off the National Science Foundation, National Institutes of Health, NASA, the science functions at NASA, NIST in a way that will protect them because they are so vital to national security, design them kind of like a castle keep, you know, the old medieval castles had several walls for defenses. We, I think, ought to think of a statutory way to design an innermost castle keep, you know, where we protect.

The sciences are really one of the most important things we can do for future generations. It is a real source of concern and I really would like your advice and guidance, the advice of your staff.

And, again, what I am thinking about is to have just a recommendation, Mr. Chairman. This Committee should always control what happens to the funding, the final amount of funding. But it would be wonderful if the recommendation for the initial budget number that we work with came from an independent panel of scientists and engineers with no political agenda that are separate entirely from the Office of Management and Budget that make a completely independent recommendation about here is where I think you ought to start as an Appropriations Committee and here is what needs to happen in the future so that it is objective, non-political and stable and predictable in the years to come.

And I would like to volunteer to help design something like that with your advice and guidance and something that the entire Subcommittee could enthusiastically get behind.

Mr. MOLLOHAN. Is the gentleman yielding back?

Mr. CULBERSON. Yes, sir. I am done. Thank you.

Mr. MOLLOHAN. I thank the gentleman for his ideas sincerely.

Mr. CULBERSON. Yes, sir. You bet. You know how fired up I am about this.

Mr. MOLLOHAN. I do.

I hear your testimony, Dr. Cicerone, that science funding, one of the goals should be to promote the development of scientists, engineers, that it is extremely important. And at the same time, it is important also to have the infrastructure that is necessary to do science.

I wonder if as we think about this and we think about that and then our funding priorities, are there areas of research that we should emphasize one over the other on the basis that one area produces people, that the spending in that area goes more to developing people, the personnel, people infrastructure versus facilities infrastructure, which can be very expensive, and what is the balance between the two in your judgment?

Mr. CICERONE. I do not know of any rigorous study, but I would favor producing people. Some of the infrastructure projects as important and as essential as they are probably have a shorter term benefit than producing people.

I have heard a few economists talk about this and they generally agree that investment in people programs has more of a multiplier effect. And given the pipeline issues we have going down into the middle schools and high schools, I think again focusing on K through 12 education would be wonderful every time we got a chance.

But it is surprising how sophisticated some of the children are. They are interested in cutting-edge issues and how you go about answering questions that we do not have to talk down to them very much.

We have done a few things over the years that have helped. They are called decadal surveys of entire fields. One of the success stories is in the field of astronomy.

For the past 40 or 50 years, the astronomers have gotten together every 10 or 12 years and it turns out they really go at each other and then they will produce a report on what is needed in the way of facilities and instruments. And they will methodically go down through the list and over a period of years get the high priority ones to be funded by working together and by demonstrating how important they are.

We did a report three years ago on earth observations that was a landmark. It tried to bring together all the cats and dogs and the incomparable instruments and all the different things they were looking at and put some order to it. And they came up with several tiers of priorities. This is what is needed first. This is what is needed second. This is what is needed third and a time table.

So to try to do that across fields and to therefore get back to your point of how you compare this kind of infrastructure investment instead of just providing broader support that is not so focused, we would have to go about it pretty methodically, I think.

Mr. MOLLOHAN. Well, off the top of your head or for the record, given your answer that our funding should always take into consideration the impact on developing the personnel infrastructure, what are the essential facilities investments that we must make at the same time? Would you be more comfortable submitting that for the record or——

[The information follows:]

The National Academy of Sciences has looked at your question in various ways over the years. In some cases, we have examined a specific field, such as astronomy, to design a roadmap of investment over the next decade across a range of needs—human resources, new observatories, and the balance between U.S.-based facilities and those overseas. There is no simple formula, and indeed, we have revisited astronomy with some frequency to modify the plan to meet changing realities.

Looking across the board at approaches to designing roadmaps for investments in infrastructure and personnel, we have conducted a number of studies that consistently emphasize a balanced set of criteria in both realms. For instance, in a 2004 study for NSF, *Setting Priorities for Large Research Facility Projects supported by the National Science Foundation,* two of the key criteria are "which projects produce the greatest benefits in numbers of researchers, educators and students enabled?" and "which projects have the greatest potential for education and workforce development?" In effect, it is essential that the criteria for investment in either equipment or training include the role of and impact on both. Likewise, in our 2006 report for NSF, *Advanced Research Instrumentation and Facilities,* the committee noted that "instrumentation is a major pacing factor for research; the productivity of researchers is only as great as the tools they have available to observe, measure, and make sense of nature." After examining the approaches taken by all federal research-funding agencies to evaluating proposals for instrumentation, and finding them inconsistent and lacking in rigor, the committee recommended that "each federal research agency should re-evaluate the appropriate balance between instrumentation and research grant, and, within instrumentation programs, the appropriate balance between small-, medium-, and large-scale instrumentation and facilities." The committee concluded that such a balance would vary by agency and by program field within each agency.

Short of a field-by-field examination of the relative needs in each field, we could obtain quick estimates by asking NSF and other agencies for a tally of how many unfunded proposals, for example for equipment and facilities, have accumulated in each field, proposals which were rated highly but could not be funded in the last several years. This tally could present how much immediate investment could be absorbed easily and quickly. In reality, the demand is much higher because in some fields, there has been no competitive program to which investigators (at universities or elsewhere) could submit requests.

Mr. CICERONE. I would. I think science has become so specialized that we really have to listen to experts from each field and then see what they have in common and see whether, for example, a regional facility which could serve, for example, one part of the country as opposed to being just in one person's back yard would work.

And the only way to get there is by having people who understand each of the related fields saying, okay, we could share this facility. This one has to be tuned up in just such a way that it cannot be shared and that kind of tradeoff that has to be looked at to see how all the fields will develop.

Mr. MOLLOHAN. And certainly another aspect of that question is, how is that taken into consideration as we look at international cooperation?

Mr. CICERONE. Yes.

Mr. MOLLOHAN. And perhaps you could discuss that in——

Mr. CICERONE. Yes.

Mr. MOLLOHAN [continuing]. Your submission.

Mr. CICERONE. I would be glad to try.

[The information follows:]

International sharing of costs and access to large facilities—there are some notable successes such as high-energy physics experimental facilities and astronomy observatories. I do not know of well accepted ways of deciding how much to use this method to support science but cases have been made that have led to international sharing of costs and benefits, mostly in the physical sciences. Hallmarks seem to be very high cost items whose benefits can be shared without diluting them too much; for example, by making observatories available to many scientists without reducing individual time shares to less than absolutely required for the goal at hand. From the point of view of science, however, we would not like to see valuable funds diverted to projects whose main virtue is encouraging international exchanges without scientific benefit—there should be high value to science. Inside the United States, some facilities have been created that can be shared in geographical regions so that students and investigators can use front line equipment without traveling abroad or even across the entire country.

Mr. MOLLOHAN. All right. Education, you notice every member of the Subcommittee just jumps right on it and it is in part at least because, and certainly so far as I am concerned, it is such a huge issue in our districts, certainly with regard to math and science and technology education. But it is a big issue for English and history and sociology and civics teaching as well.

But looking at the STEM subjects for a moment, we are really yearning for the answer. And I am sure the folks that testify before the Committee are anxious to give us the answer.

You are not responsible for K through 12 secondary education obviously. At the same time, your thoughts about its importance are extremely motivating to us to try to see how we can impact that in a positive way through your expertise, through NASA, as you point out, NASA is being very active in that, and through any other of the science accounts under our jurisdiction.

But it seems to me there are two sides to this problem. When folks come up and testify that we are behind, sometimes I think that part of that testimony is to motivate us to spend more money in science generally. And certainly that is true because it is a part of any program you put forward or you initiate.

But there are two pieces. Number one is the product that is produced in K through 12 and delivered to the universities and/or matriculates to the universities and then hopefully into graduate and postgraduates and docs and post-docs and all of that.

Producing a sufficient pool of students or maximizing those who have a capability to aspire to graduate study in science, majoring in science at universities, producing that, finding those is one issue. How do you do that?

And there is a lot of looking at how that happens, but there is very little of coming back and saying, okay, we have prototyped this and this is what really has to happen from kindergarten through post-doc to maximize the talent that exists in the United States.

And it seems to me based on your testimony and everybody else's that that is increasingly important as other countries provide opportunities for their students who we have relied upon as you have testified.

So while it has always been important, it is increasingly more important. And so I guess how do we maximize it? You are not the Department of Education, but you certainly have an interest in it.

And Mr. Wolf asked questions about, you know, at what age are youngsters naturally interested in science and then when do they drop off and then you lose them forever.

Those questions are very important for us to answer here on the Committee and also, I think, in the Education Committee.

You have all kinds of reports that, well, scientists should teach science. Well, that probably works in the Washington area. It probably works around, I do not know, Princeton University. It does not work so well in a number of counties in my congressional district, probably about 20 out of the 21, because they are not there. That may be overstated.

So it seems that we have to teach the teachers to know science and know mathematics when they go into the field. But it would be very helpful if we looked at that at your level.

What does the educational system have to do in order to achieve this finding, identifying, mining, if you will, the minds that are able or capable and inclined to go into the higher sciences? You know, what does need to be there? Does the teacher who is coming out of the schools of education need also to have a major in biology if they are going to teach biology or biology and chemistry? What is needed?

And so you can just tell the education departments' deans that if you are going to really get to kindergarten through twelfth grade, then the teachers who go there, not only do they have to be able to teach, but we cannot assume that because they have a teaching degree and they know how to teach that they can teach other things.

So, look, it is a no-nonsense thing. You have to know chemistry if you are going to teach chemistry. So if you are graduating students who are interested in teaching the sciences, then these students have to have a science degree of some sort.

That definitiveness, this is what is needed, would seem to me to be critical and maybe it is out there. I mean, maybe. I really do not know that. But I would just like your comments on that rambling.

Mr. CICERONE. Well, I think you are on to something.

Mr. MOLLOHAN. Thinking.

Mr. CICERONE. A lot of evidence shows that great teachers can teach almost any subject to children up to a certain age. There is argument about what that age is, but let us call it maybe fourth or fifth or sixth grade. But beyond that time, to be able to teach all the specialized subject, the teacher needs some specialized background himself or herself. That is kind of what you were getting at.

And then most of the other evidence shows that the quality of the teacher is the biggest single thing that goes into success in school. Of course, the parental involvement probably still dominates. We just do not know how to measure that.

Okay. So if you want to focus on teachers who have some specialization themselves or some content basis, the problem immediately arises that they have other job opportunities. So how can we attract them into teaching? How can we retain them? How can we give them a network of people who they can work with, where they can get extra materials, how they can stay up to date, how they can have summer research opportunities in companies and so forth?

And those are the kinds of local actions that are taking place around the country, some of them very successful where there will be a group of citizens or a corporation that decides to basically see to it that teachers with those qualities are encouraged to stay for more than two or three years in teaching, that they are given, for example, extra summer employment and extra help.

And unfortunately, because of our system in the United States, it is a patchwork, but there are hundreds and hundreds of good programs out there and some of them going off in special directions like, for example, computer-assisted instruction where there are now gifted, dedicated people developing kinds of software to teach children mathematics which will allow students to go off in all kinds of different directions using the same software, proceeding at their own pace and then providing feedback to the teachers to say did you know that your student X who is using this software is off doing that now.

I have seen some fabulous developments recently. So we have got a thousand flowers blooming and it does not seem like we have any way to capture it all and to distill it and to take the best practice from here over to here. We have this patchwork that is hard to deal with.

But lots of good things are happening out there to the benefit of thousands and thousands of students, but we look around and see other places where it is not happening at and it is very frustrating.

[The information follows:]

The major (or only) experience of which I am aware of a large increase in scientific funding which led later to discouragement amongst scientists is that of NIH in the last several years. Something similar might have happened immediately after Sputnik but I am not sure.

At NIH, between the years 1998 and 2003, research funding was doubled so that biomedical investigators from American universities met with more success in competitions for NIH funds. A higher fraction of proposals succeeded and typical grant sizes increased. More investigators were encouraged to submit proposals to NIH. In addition, some of the awards were granted for longer periods of time, and simultaneously, NIH was given more tasks by the federal government. Consequently, after a relatively short time, little flexibility was left and both new and continuing investigators began to experience higher rejection rates. The current situation has discouraged many investigators and has probably led some young people to avoid entering biomedical fields. It might have been avoided if more attention had been paid to the demography of investigators and the duration, size and numbers of awards to them, and if funding to NIH and other roles for NIH had been more predictable, or if funding increases had continued.

I am sure that NIH leaders can provide more detailed analysis.

Mr. MOLLOHAN. Thank you.

Would you for the record, if you feel comfortable doing this and it certainly would be helpful for the Committee, as we look at this increased funding for science and the accounts in our jurisdiction, we very much want to reach the balance point. We do not want to create a baseline and a commitment to a percentage increase that we cannot sustain.

You alluded to the fact that NIH perhaps could not sustain the increases over a certain period of time. Could you for the record comment on that question and give us the guidance that you feel you are capable or able to do or comfortable doing with regard to the accounts that we have jurisdiction of. And if you would like to comment on that, I would invite you to do that.

Mr. CICERONE. Just real quickly. I do not have enough of the numbers in my head. But where I would start would be to see where the backlog is of all the really valid and critically evaluated proposals that have come into these agencies and see where we stand after this stimulus spending and how to move into the future and then what the age distribution of those successful investigators is.

Are we dealing with a lot of people who are just starting, who will presumably want to continue after three or four years? Are we dealing with a fraction of people who are at the end of their careers, to try to look at the demography of it? And it is hard to know exactly what number to say without going into those dynamics.

Mr. MOLLOHAN. Mr. Wolf.

Mr. WOLF. Well, thank you, Mr. Chairman. This has been a good hearing.

And I know the Chairman knows this one Committee. We have a rural county in my district, Clark County, unbelievable school system, if you look at the U.S. News or World Report, and I think a lot of times, personnel is policy. They have had great leadership and, you know, they are doing terrific, unbelievably. You might just take a look at Clark County and look at the scores and look how they are rated.

I wonder, and you do not have to answer this or if you want to, I would love to get you, I wonder if we could be losing the American work ethic to a certain degree.

This past summer, you know, at the beach and the summer before down in Nags Head and one time in New Jersey, every young person working on the beach or working in the arcades or working, they were from Bulgaria, they were from Romania, they were from Russia. Well, gee, that is what I did and I worked construction for McClusky Construction. I did all these summer jobs.

Now, I would like to hear maybe the kids are all at summer camp, at science summer camp working. And so if they are, then I am glad the Bulgarians are working. But if they are not, and it really troubles me.

I had an experience. I was down at Nags Head and it was just when the Russians had invaded Soviet Georgia. And there was a big article there about Yeltsin, not Yeltsin, Putin, and there were two Russian young ladies there. And I said Putin and they made a comment pretty negative about Putin.

But here everyone was from an eastern European foreign country hungry, doing good work. They were hungry because they wanted to earn. And I wonder if there has been some diminution of the work ethic in the country. If you have any thoughts on that.

Mr. CICERONE. You and I should compare stories about where we have worked in our lives. I would love to do that.

No. It is serious. It really is a question, can we change our behavior by looking at things rationally and seeing what is coming or does it take a crisis to change our behavior because I think there is some truth to what you just said.

We have had it pretty easy here for a long time.

Mr. WOLF. Yeah. Well, I thank you very much.

Thank you, Mr. Chairman.

Mr. MOLLOHAN. Well, we are certainly facing a crisis.

Mr. CICERONE. There is the opportunity.

Mr. MOLLOHAN. Yes. Maybe that is the opportunity.

Dr. Cicerone, thank you very much for your testimony and your good work. I know the Subcommittee has appreciated it. And as Mr. Wolf expressed, I think it has been an excellent hearing principally due to your fine testimony.

Thank you for appearing before us today. And there will be a few questions submitted for the record which we will submit to you after the hearing, if you would be kind enough to consider answering them and be responsive to some of the requests during the hearing.

Thank you very much to you and your fine organization for being here today and the good work you do every day.

Mr. CICERONE. Thank you.

Additional Questions from Rep. Aderholt May 26, 2009

1. You mention the importance of philanthropy in providing funds for essential research. What effect will the economic downturn have on people's ability to give and how would a sharp decrease impact research and development?

Reply - Philanthropy is a very American phenomenon. Until recently it was uniquely American but now there is significant philanthropy in Australia, the United Kingdom and Germany. We have major philanthropic foundations that support science, as do smaller individual and family foundations and some corporate foundations. Most of their support for science goes to universities and independent research institutes and this support contributes to salaries for researchers and support staff, travel, equipment and very importantly at universities, to student scholarships, graduate fellowships and endowed professorships. In most fields, federal support is much larger than private support but philanthropy is still very important and it gives America an advantage.

No one knows how much the economic downturn of 2008-09 will decrease philanthropic contributions. Grantmaking foundations are required by law to give away at least 5% of their endowment annually but the endowments of foundations have shrunk so their required giving and their ability to give are diminished. Contributions from individuals are often based on the value of appreciated assets (due to favorable tax law) and there are fewer of those assets now. Thus, we expect diminished support from philanthropy.

I might add that the psychological impact to a student who receives support from donors is very positive and I hope that donors can find ways to continue to contribute, even at diminished rates, during this current downturn.

2. Some rural and less affluent areas of the country do not have the resources to provide a robust science department, which can lead to a hands-on experience that hooks a young student on the sciences. Given this shortcoming, what steps and programs can be undertaken to encourage students in these areas to pursue education and careers in science?

Reply –
I sympathize with this kind of situation. In college, I met students who had gone to high schools which had good science laboratories, the best of teachers and modern curricula. Those of us who had not attended such high schools had a hard time competing and catching up. And it is hard to get interested in a subject in the first place if you have no exposure to it.

In our country, issues of K-12 education are almost entirely under local and state control rather than federal. I can suggest two types of federal programs which can help. One is a summer session aimed at high school students perhaps in tenth or eleventh grade where they are given intensive instruction in mathematics, physics, chemistry or biology along with a research experience; I have seen such a program to be successful. The program is at a college campus and requires the students to live there away from home but usually in their home states. Federal funding could pay for scholarships for the students for six or eight weeks. I have seen students from relatively poor high schools gain exposure to serious courses and exciting extra activities focused on science and mathematics, students who are strongly and positively influenced by these experiences who go on to careers in science.

The second idea would be to support current and new teachers with summer programs aimed at providing new materials and ideas to them and helping them to improve their teaching. Once again, universities in each state could be the centers to serve teachers in the state's school districts.

A number of other innovative public-private partnerships programs are summarized in a recent report from the Woodrow Wilson International Center for Scholars: "Stakeholders in Student Success".

3. You state that "American achievements and activities in science have created much goodwill worldwide". How can this goodwill be put to use to improve America's attraction and retention of top researchers and professors?

Reply -
The United States has benefited enormously from foreign students who study and do research in our universities and from more senior scientists who come to work in our universities and research institutions. As I said in my March 3, 2009 testimony, an impressive stream of such visitors has been coming to the United States for many years now and these people have given big boosts to American science and industry. Benefits accrue to the U.S. when these people stay and become productive, permanent residents or citizens or when they return to their native countries where they become lifelong friends and collaborators. Many American travelers notice that leadership positions in many countries, especially developing countries, are populated by people who were educated in the United States in science or engineering, medicine, economics and other subjects. Such foreign leaders are familiar with, and usually friendly to the United States.

The dominant factor in attracting top-notch students and scientists from other countries is opportunity. American science is open, there are generally adequate or better resources here, like laboratories and equipment, and the atmosphere is competitive. For some foreign visitors, the prospect of later permanent employment is very important. Recognizing the value of foreign students and visitors, many other countries are now working hard to attract such people in competition with the U.S. by providing financial support and other incentives, by creating graduate education programs taught in English, and by making foreign visits easier. Simultaneously, the U.S. has made it more difficult for foreign students and visitors to enter the U.S., and to extend their visas and to find employment while economic opportunities elsewhere are beckoning, for example, in India, China and Korea. Data on numbers of foreign students are entering the U.S. and how many of them stay after taking degrees are available from our National Science Foundation.

To improve America's attraction and retention of top researchers from other countries, we must recognize that there is now more competition for this talent. We must do more to draw them here, for example, by supporting students from developing countries and supporting modern facilities in their home countries where some of them might return, so that they can maintain collaborations with American scientists. We should encourage international scientific meetings to be held in the U.S. and subsidize them if needed. We should encourage our federal agencies to enter into projects with foreign partners and the Department of State to post scientists in many of our embassies worldwide.

At the same time, we should remove barriers to foreign visits that are not needed for security. Specific suggestions include: "deemed export" policies that unnecessarily prevent foreign students from participating in university-based research. We should grant visa extensions for foreign students who receive Ph.D. degrees here to encourage them to find jobs, and we should grant more long term visas for science and engineering doctoral students. Visiting lectureships for foreign professors could be greatly expanded.

TUESDAY, MARCH 3, 2009.

THE PLACE OF NASA AND NSF IN THE OVERALL SCIENCE ENTERPRISE

WITNESSES

LENNARD FISK, UNIVERSITY OF MICHIGAN, FORMER NASA ASSOCIATE ADMINISTRATOR FOR SPACE SCIENCE AND APPLICATIONS
SAMUEL M. RANKIN, III, ASSOCIATE EXECUTIVE DIRECTOR, AMERICAN MATHEMATICAL SOCIETY

OPENING STATEMENT BY CHAIRMAN MOLLOHAN

Mr. MOLLOHAN. The hearing will come to order. Good afternoon, Dr. Fisk and Dr. Rankin. And Dr. Rankin, as the only mathematician appearing before us today, or even the rest of the week, Happy Square Root Day.

Mr. RANKIN. The first time I have heard of it.

Mr. MOLLOHAN. Well, it was not too long ago it was the first time I heard of it. And I understand if we do not celebrate today then we have to wait until April 4, 2016. So how are you going to celebrate?

Mr. RANKIN. I have not thought that far.

Mr. MOLLOHAN. Stumped you on the first question. Well, welcome to the hearing. This morning we received an overview of science in the United States. This afternoon we will examine the role of two research agencies under our jurisdiction, NASA and NSF.

Following the issuance of the report, Rising Above the Gathering Storm, there has been a bipartisan effort to double the fiscal year 2006 funding of NSF, along with NIST, and the Department of Energy Office of Science over ten years. The stimulus funding provided in the American Recovery and Reinvestment Act of 2009 increased fiscal year 2009 funding for NSF by roughly 50 percent, while providing a roughly 8 percent boost to NASA science.

Looking forward, it is important for this Subcommittee to understand the relative roles and status of the different research agencies, and we look forward to learning more from Dr. Fisk about NASA and from Dr. Rankin about NSF. Gentlemen, your statements respectively will be made a part of the record. And before asking you to testify I would like to call upon our Ranking Member Mr. Wolf.

Mr. WOLF. No questions.

Mr. MOLLOHAN. Okay, thank you. Gentlemen, if you will proceed? Dr. Fisk, will you go first?

Mr. FISK. Thank you very much, Mr. Chairman and Members of the Subcommittee. Thank you very much for inviting me here today. For the record I am Lennard Fisk. I am the Thomas M. Donahue Distinguished University Professor of Space Science at the University of Michigan. And I also served from 1987 to 1993 as the NASA Associate Administrator for Space Science and Application, and until last July as the Chair of the National Research Council Space Studies Board.

There have been, as you noted in your opening remarks, there have been several legislative initiatives that recently have treated science in NASA as less important to the nation than other scientific pursuits. The highly acclaimed National Research Council report Rising Above the Gathering Storm, which called for substantial investments in the physical sciences, was effectively silent on NASA. The legislative initiatives that followed from this report, for example the America Competes Act, did not focus on NASA science. And recently, the American Recovery and Reinvestment Act of 2009 was appropriately supportive of the National Science Foundation and the DOE Office of Science, and yet in NASA the only science discipline that received substantial funding was earth science. And then it provided only partial recovery from the disastrous decline in funding that had occurred in the previous decade.

Now, as a practicing space scientist, and someone who throughout much of my career has been concerned with science policy, I can find no logic in the judgment that NASA science is of less importance than other scientific disciplines. And in my written testimony I have discussed the impact each of the disciplines of NASA science has had on society, and most important on our nation's future. These arguments can be repeated for many different science disciplines, and they are no less compelling for NASA science.

Now, NASA science asks and is attempting to answer the most fundamental human questions. What is our place in the cosmos? Are we alone? NASA science is revealing the wonders of our own solar system and the resources it may hold for us. NASA science is attempting to understand the controlling body of our solar system, the sun, and the space environment through which we fly our satellites and send our human explorers. NASA science is attempting to make it possible for humans to live and work in space. And NASA science is attempting to answer the single most important question of our age. What is the future of the climate of the earth? And what are we as humans doing to it?

We need to recognize that space has become part of the underlying infrastructure of our civilization. We have weather satellites. We communicate through satellites. Particularly the visual images of television that bring to each of us an awareness unprecedented in human history of what is happening everywhere in the world at all times. We have global positioning satellites which help us fly our airplanes and find our way in automobiles. We have remote sensing satellites that provide high resolution images from around the world. All this is simply part of the basic infrastructure of our civilization. We do not particularly marvel that it is available. We assume it will be and we think no further about it.

Indeed, when we consider the impact of space on our society we have to look no further than the global interconnections that have flourished in the last few decades. We live in a global economy. Corporations are multinational. Manufacturing and trade are worldwide. Countries that in previous generations might have been suspicious enemies are now dependent upon each other for resources and for marketplaces for their manufactured goods. This has had a very real, stabilizing effect on world peace because detailed knowledge of what is happening everywhere in the world reduces fear and makes possible the full engagement among societies.

We need to recognize that space is an integral part of our foreign policy. Our activities in space have profound impact on the image of our nation and provide extraordinary opportunities for us to be strategic leaders in a world that is increasingly judging space to be important.

The peoples of the world are increasingly dependent upon space for their basic activities in their everyday lives. There are space races developing in Asia. And every nation that wishes to gain respect as an important player on the world stage has concluded that they need to acquire a recognized space capability.

The United States has an opportunity to be a strategic leader in this worldwide effort to become a true space faring civilization and provided that we lead not by dominance but rather by example, and in cooperation we will realize our destiny as a great nation capable of making the world better for all the world's peoples.

At the foundation of our space activities is science in NASA. Science often provides the initial reason why we explore a new region of space, or even a new region of the electromagnetic spectrum. The technology developed for space, for scientific exploration, enhances our other space activities and finds its way into our economy. The youth of our nation are inspired by the brilliance of our scientific achievements in space and encouraged to pursue careers in science and engineering.

The people of the world ask the same fundamental questions that we do about our place in the cosmos. They expect the United States as a great nation to use its capability in space to enlighten. The people of the world are frightened by the pending changes in our climate and they expect the United States as a strategic leader to ensure that we create the capabilities in space to observe and to understand our changing climate.

We invest in scientific research because it provides a foundation of knowledge on which we depend to advance our civilization. We invest in space because it is essential to the future of our nation, for the stewardship of our planet, and for the growth of our economy, and for our position as a world leader. It follows very simply, then, that the science of space, which is space and earth science in NASA, is as important to our nation's future as is any other scientific discipline.

I will be happy to answer any questions you might have.

[Written statement by Lennard A. Fisk follows:]

TESTIMONY BEFORE THE HOUSE COMMITTEE ON APPROPRIATIONS
SUBCOMMITTEE ON COMMERCE, STATE, JUSTICE AND RELATED AGENCIES

THE PLACE OF NASA SCIENCE IN THE OVERALL SCIENCE ENTERPRISE

Lennard A. Fisk
University of Michigan

March 3, 2009

Mr. Chairman, members of the subcommittee, thank you for inviting me here to testify today. My name is Lennard Fisk, and I am the Thomas M. Donahue Distinguished University Professor of Space Science at the University of Michigan. I also served from 1987 to 1993 as the NASA Associate Administrator for Space Science and Applications, and until last July as the Chair of the National Research Council Space Studies Board. The testimony I am giving today is on behalf of myself.

There have been several legislative initiatives recently that have treated science in NASA as less important to the nation than our other scientific pursuits. The highly acclaimed National Research Council report, Rising Above the Gathering Storm, which called for substantial investments in the physical sciences, was effectively silent on NASA. The legislative initiatives that followed from this report, e.g., the America Competes Act, did not focus on NASA science. The recent American Recovery and Reinvestment Act of 2009 was appropriately supportive of the National Science Foundation and the DoE Office of Science, yet in NASA the only science discipline that received substantial funding was Earth science, and then it provides only a partial recovery from a disastrous decline in funding that occurred during the previous decade.

As a practicing space scientist, and someone who throughout much of my career has been concerned with science policy, I can find no logic in the judgment that NASA science is less important. In later sections of this testimony, I discuss the impact that each of the disciplines in NASA science has had on society, and its importance to our nation's future. These arguments can be repeated for many different science disciplines, and they are no less compelling for NASA science.

NASA science asks and is attempting to answer the most fundamental human questions: What is our place in the cosmos; are we alone? NASA science is revealing the wonders of our own solar system, and the resources it may hold for us. NASA science is attempting to understand the controlling body of our solar system, the Sun, and the space environment through which we fly our satellites and send our human explorers. NASA science is attempting to make it possible for humans to live and work in space. NASA science is attempting to answer the single most important question of our age, what is the future of the climate of the Earth, and what impact are humans having upon it.

We need to recognize that space has become part of the underlying infrastructure of our civilization. We have satellites that provide data for sophisticated forecasting models to predict the weather throughout the world. We communicate through satellites, particularly the visible images of television that bring to each of us an awareness, unprecedented in human history, of what is happening everywhere in the world at all times. We have direct broadcasting that brings the television signals directly into our homes. We have global positioning satellites, which help us fly our airplanes, let us find our way in automobiles. We have remote sensing satellites that provide high-resolution images from around the world. All this is now part of our basic infrastructure as a civilization. We don't particularly marvel that it is available. We assume it will be and think no further about it.

Indeed, when we consider the impact of space on our society, we have to look no further than the global interconnections that have flourished in the past few decades. We live in a global economy. Corporations are multinational. Manufacturing and trade are worldwide. Countries that in previous generations might have been suspicious enemies are now dependent upon each other for resources, and as marketplaces for their manufactured goods. This has had a stabilizing effect on world peace. Detailed knowledge of what is happening everywhere in the world, and the ability to share that knowledge, reduces fear and makes full engagement among societies possible and routine.

We need to recognize also that space is an integral component of our nation's foreign policy. Our activities in space have a profound impact on our image as a nation, and provide extraordinary opportunities for us to be strategic leaders in world that is increasingly judging space to be important. The peoples of the world are increasingly dependent on space for basic activities in their everyday lives. There are space races developing in Asia, and every nation that wishes to gain respect as an important player on the world stage has concluded that they need to acquire a recognized space capability. The United States has an opportunity to be a strategic leader in this worldwide effort to become a true spacefaring civilization, and provided that we lead, not by dominance, but rather by example and in cooperation, we will realize our destiny as a great nation, capable of making a better world for all of the world's peoples.

At the foundation of all our space activities is science in NASA. Science often provides the initial reason for why we explore a new region in space, or even a new region of the electromagnetic spectrum. The technology developed for scientific exploration enhances our other space activities, and finds its way into our economy. The youth of our nation are inspired by the brilliance of our scientific achievements in space, and encouraged to pursue careers in science and engineering. The people of the world ask the same fundamental questions that we do about our place in the cosmos, and they expect the United States, as a great nation, to use its capabilities in space to enlighten. The people of the world are frightened by the pending changes in our climate, and they expect the United States, as a strategic leader, to ensure that we create the capabilities in space to observe and to understand the climate, and predict its future.

We invest in scientific research because it provides the foundation of knowledge on which we depend to advance our civilization. We invest in space because it is essential to the future of our nation, for the stewardship of our planet, for the growth in our economy, for our position as a world leader. It follows, therefore, that the science of space, space and Earth science in NASA, is as important to our nation as any other scientific discipline.

The following sections discuss each of the science disciplines of NASA –Astrophysics, Planetary Exploration, Heliophysics, Life & Microgravity Science, and Earth science –and the contributions that it has made, why each is important to our nation, and some of the challenges they are facing.

Astrophysics

The Space Age has had a profound impact on our society and how we view ourselves as humans, how we relate to each other, how we reflect on our place in the cosmos. For most people, I suspect, the change in attitude, the penetrating new insight, followed from the historic picture of Earth taken by the crew of Apollo 8 en route for the first time to the Moon. Earth is beautiful, isolated in the cold darkness of space. We look fragile. Who would not conclude that we have a responsibility to protect our home, to ensure that it remains a safe haven for us in the inhospitable cosmos?

For others there was a profound awakening when Voyager, leaving the Solar System, turned its cameras to look back and see the planets, including Earth, as mere dots of light. How vast space is; how alone we are, at least in our local neighborhood.

Of most importance, there has been the steady drumbeat of astronomical discoveries. Space is the ideal location from which to observe the universe. Our atmosphere shields us from many forms of radiation, and even in visible light, which does penetrate through the atmosphere, it can be distorting. And so from virtually the beginning of the Space Age, the spacefaring nations of the world have launched ever more sophisticated astronomical observatories, and greatly expanded our knowledge of the universe, and greatly expanded the questions we can ask, and can expect eventually to answer.

We have observed the remnant radiation from the Big Bang that began our universe. We have found that the universe is continuing to expand, driven by a force that we don't yet understand. We have discovered that there is matter in the universe, a lot of it, which we can't yet observe. We have seen galaxies forming at the beginning of the universe, and stars forming in our own galaxy. We have discovered planets around other stars, many of them, so many that it is ever more likely that there are other earths and perhaps other civilizations comparable to our own.

We have generated marvelous images from our great observatories peering into the universe in all the different wavelengths of light. The public, in many cases, cannot fully understand the scientific discoveries enabled by these images. But they have no difficulty in marveling at the beauty and the majesty of the universe, and its unfathomable vastness. The Copernican revolution of the early 16th century displaced Earth and thus humans from the center of the universe, showing that we are just another planet orbiting the Sun. I doubt the public of that time paid a great deal of attention, but the Copernican revolution ultimately affected society and its attitudes, even religion.

We are in the midst of another such revolution, which in time will have equally profound consequences. As the vastness of the universe becomes known and appreciated by all, and how common are our planetary circumstances, we become ever more insignificant. But perhaps we will view that insignificance in the most positive light—that our tensions and conflicts, which are our constant, everyday concern, are truly insignificant in the grand scheme of the cosmos.

Planetary Exploration

We have also explored our own solar system, revealing the wonders and the opportunities it contains. Before the Space Age the planets were observed, with only very limited resolution, by telescopes. Now we have been to them all. Depending upon where you stand on whether Pluto is a planet, we will be there shortly also. It has been a systematic process. First fly-bys that produced many surprises. Then orbiters about many of the planets—Venus, Mars, Jupiter and Saturn, with a Mercury orbiter currently underway. And in the case of Mars, there have been landers with their rovers that roam the surface, and look for water and maybe life.

The epic journey of exploration of the Space Age has been the Voyager spacecraft, which visited Jupiter, Saturn, Uranus, and Neptune, and now the two Voyagers are en route out of the Solar System, both having crossed the termination shock of the solar wind, where the supersonic expansion of the solar atmosphere, the solar wind, goes subsonic and begins the process of merging into the local interstellar medium.

There has been unprecedented excitement in the discoveries of each planetary mission. The fly-bys were events that the public stayed up and watched. The rovers on Mars have been adopted by the public, and followed on the internet with each new canyon and rock formation that is explored.

In the United States and elsewhere in the world we are witnessing a fascinating difference among the generations as to what is impressive. To the older generations who witnessed Apollo, human space flight is impressive. The astronauts were true heroes. However, to the younger generation, who are steeped in technology, who vicariously participate in all sorts of adventures through their computers, rovers on Mars are more impressive. The rovers are based on the latest technology. They are doing something we have never done before. And wouldn't it be better still if the younger generation could drive them themselves?

Heliophysics

We have also learned much during the Space Age about our Sun and the space environment it creates, and in which we live. Last year was the 50th anniversary of the seminal paper by Gene Parker, which predicted that the outer atmosphere of the Sun, a million-degree plasma, would expand supersonically into space creating a solar wind. Parker's paper was highly controversial at the time, nearly rejected by the journal. It took the first interplanetary mission, Mariner 2, in 1962 to prove definitively that Parker was indeed correct. The atmosphere of the Sun expands to fill a large region of space, to carve out a heliosphere from the local interstellar medium. We now know from Voyager that the supersonic flow of the solar wind extends to 100 times the distance from the Sun to Earth. Along the way, the solar wind impacts the magnetic fields of the planets and creates dynamic magnetospheres around each of the planets that has a strong magnetic field.

The engine of the space environment of the Solar System is of course the Sun itself. Before the Space Age, the Sun was viewed as a relatively benign object, a constant source of light and energy, on which we depend for life. With the advent of space observations in many different wavelengths of light, the true character of the Sun has been revealed. Its surface and lower atmosphere are a cauldron of dynamic processes, driven by strong magnetic forces that can eject large amounts of high-energy particles, and at times large amounts of matter, which can affect Earth and other planets.

This is the space environment through which we fly our satellites, and hope some day to fly humans. It is not a friendly place. It is a place where damage can be inflicted on our technologies, and if we are not careful, death inflicted on our human explorers. We have made much progress in documenting the range of conditions that can occur in our immediate space environment. We have made only limited progress in predicting the conditions in space. Yet, if our societies wish to make maximum use of the opportunities that space provides, we will indeed need a reliable predictive capability.

The Sun is a cyclic object. It has an 11-year cycle in its activity. Its magnetic polarity flips every 11 years, for a 22-year magnetic cycle. The causes of the cycles, their length, the strength of the activity, all these are only primitively understood, and not reliably predicted. Yet there is evidence of the imprint of these cycles on life on Earth, through means we do not understand. As we sort through the undeniable impact of humans on the climate of Earth, we need to make sure that we understand all the natural forcing functions, and can predict their occurrence and their impact.

Life and Microgravity Science

During the 50 years of the Space Age, we have also taken the first feeble steps in learning to live and work in space. The efforts to use the space environment, particularly the microgravity environment, to do research that has application on Earth, has for the most part been an unfulfilled promise. It can be argued that this unfulfilled promise results from the lack of flight opportunities. Missions have been few and of relatively short duration. The ISS, which is designed to provide the opportunities to pursue this research, is only now being completed.

What we have done, however, over these 50 years, is learned to live in space and to construct things there, which has established the usefulness of humans in space. We have demonstrated that humans can remain in weightlessness for extended periods. Since this experience has been within the protective shielding of Earth's magnetic field, and thus relatively free of radiation, the radiation hazard of space and its consequence for humans, and whether weightlessness and radiation together are a serious complication still remain to be determined.

Perhaps the most impressive feature to date of the ISS is that it has been built. It is the fruit of cooperation among many spacefaring nations; an extraordinary construction project in which many different pieces of hardware had to come together and be assembled on orbit. We have certainly proven that we can work together as spacefaring nations to achieve an impressive accomplishment.

Earth Science

Finally there is Earth science. No other science discipline has had more direct impact on society than Earth science. And space has made that impact possible. We have passed through a tipping point in the past 50 years, to where now our everyday activities, our use of natural resources, are having a global impact on the future of the planet. The sustainability of Earth to support human life is in question. This is a global problem. And the global perspective of observations from space is required to understand what is happening to Earth; what our future holds.

We have also learned, strongly influenced by the global perspective provided by space observations, that Earth is a highly coupled system. The atmosphere, the oceans, the cryosphere, the land surfaces, the biosphere are all coupled, in an intertwined system, in which complex feedback mechanisms are possible. Understanding Earth, and what we as humans are doing to it, is not an easy problem. It does not do any good simply to say that Earth is warming as a result of fossil fuel emissions. That is certainly so. But the knowledge that is required is: what are the regional consequences? How will precipitation patterns change, or growing seasons? Exactly how much will sea levels rise? A foot makes a big difference.

It will take many observations from space, and much of the world's scientific talent to understand exactly how Earth works, and to predict exactly what we as humans are doing to it; and to monitor and evaluate our efforts to protect the future of the planet, should we ever be so wise as to engage in a serious effort to avoid the pending catastrophe.

In the late 1980s NASA made a serious effort to embark on a major program to make comprehensive observations of Earth, and to support the science needed to understand the observations, with its multi-billion dollar Mission to Planet Earth. That program has been largely abandoned under the same government policies that treated the human influence on the climate as an uncertainty. The perceived economic consequences of any meaningful response was considered to be so overwhelmingly negative that ignorance of what our future holds is a preferred state. Generations to come will not be kind to us that we treated the future sustainability of the planet in so cavalier a fashion.

At least we can say that one of the most important impacts of space on society is that space has provided the basis for our growing human awareness that we are highly interdependent. What China does to the atmosphere affects the United States. What the United States does to the atmosphere affects Europe. What we all do to heat Earth affects the polar regions. And so on. Most of us know this. Most of us came to this realization because of the global perspective of Earth that has been provided by space observations. Most of us would like to see wise decisions being made to protect that fragile globe that we saw from Apollo 8, and be sure that it remains our hospitable home in the hostile and lonely environment of space.

LENNARD A. FISK

Lennard A. Fisk is the Thomas M. Donahue Distinguished University Professor of Space Science at the University of Michigan, where he is the current Henry Russel Lecturer, the highest honor the University bestows upon a senior member of its faculty. Prior to joining the University in July 1993, Dr. Fisk was the Associate Administrator for Space Science and Applications of the National Aeronautics and Space Administration. In this position he was responsible for the planning and direction of all NASA programs concerned with space science and applications and for the institutional management of the Goddard Space Flight Center in Greenbelt, Maryland and the Jet Propulsion Laboratory in Pasadena, California.

Prior to becoming Associate Administrator in April 1987, Dr. Fisk served as Vice President for Research and Financial Affairs and Professor of Physics at the University of New Hampshire. In his administrative position, he was responsible for overseeing the University's research activities and was the chief financial officer of the University. Dr. Fisk joined the faculty of the Department of Physics at the University of New Hampshire in 1977, and founded the Solar-Terrestrial Theory Group in 1980. He was an astrophysicist at the NASA Goddard Space Flight Center from 1971 to 1977, and a National Academy of Sciences Postdoctoral Research Fellow at Goddard from 1969 to 1971.

Dr. Fisk is the author of 200 publications on energetic particle and plasma phenomena in space. He is a Member of the National Academy of Sciences (NAS) and the International Academy of Astronautics (IAA); he is a Foreign Member of Academia Europaea and a Fellow of the American Geophysical Union. He served as Chair of the NAS Space Studies Board from 2003-2008; he is a co-founder of the Michigan Aerospace Corporation and a Director of the Orbital Sciences Corporation. He is the recipient of the NASA Distinguished Service Medal in 1992, the AIAA Space Science Award in 1994, and the IAA Basic Science Award in 1997 and 2007.

He is a graduate of Cornell University. In 1969, he received his doctorate degree in Applied Physics from the University of California, San Diego.

Mr. MOLLOHAN. Thank you, Dr. Fisk. Dr. Rankin.

Mr. RANKIN. Thank you, Chairman Mollohan, Ranking Member Wolf, and Committee members. I thought what I would try to do is give a little bit of an idea of what I think is the culture of the interaction between NSF and the scientific community.

The National Science Foundation is the only federal agency that supports basic research across all fields in engineering, and all levels of science and engineering education. Although the agency's annual budget represents only 4 percent of federal R and D, it provides nearly half the support for non-medical basic research at colleges and universities. The main source of federal support for basic research at colleges and universities in the fields of mathematics, social sciences, non-medical biology, and computer science, comes from the NSF, as well as over 40 percent of support in the physical sciences, engineering, and the environmental sciences. Through the Directorate of Education and Human Resources the NSF supports activities that ensure a diverse, competitive, and globally engaged science, technology, engineering, and mathematics work force.

An interesting number here is that the NSF invests over 90 percent of its budget directly to support research at colleges and universities, in all fifty states. This support reaches over 2,000 institutions and nearly 200,000 researchers, post-doctoral fellows, trainees, teachers, and students every year. NSF receives well over 40,000 grant proposals each year, making over 11,000 awards, mostly to individual investigators at colleges and universities and other public and private institutions. Through its merit review process NSF identifies the best ideas and the people to develop these ideas, who through their work advance the frontiers of knowledge in science and engineering.

There are six Research Directorates and one Education Directorate. Most of the funds for research are allocated to investigators through these directorates. Research proposals are received as a response to solicitations issued by disciplinary divisions within these directorates and NSF offices (few offices also distribute funds), or an individual investigator can submit an unsolicited proposal. In either case, the proposal goes through a merit review process which assesses the intellectual merit of the proposed project and the broader impacts of the project.

It is through the directorates that the science and engineering disciplinary communities have most of their interaction with NSF. In fact, over 45,000 scientists and engineers serve on merit review panels or as proposal reviewers each year, and therefore have direct impact in setting standards for research. NSF also derives input from disciplinary communities through directorate and advisory committees, and committees of visitors. Advisory committees provide advice on program management and performance as well as input on the impacts of policies, programs and activities in the disciplines that are funded through the directorate. Committees of visitors provide input on the quality and integrity of program operations and program level technical and managerial matters pertaining to proposal decisions, and comments on how the outputs and outcomes generated by awardees have contributed to the attainment of NSF's mission and strategic outcome goals.

This characteristic of continuing interaction with the science and engineering disciplinary communities allows NSF to keep abreast of research in disciplinary fields, understand the needs of the scientific community, and be responsive to it. Conversely, the science and engineering disciplinary communities believe that they are an integral part of the process in helping move U.S. research and innovation forward. This includes those investigators making transformational discoveries to those scientists and engineers establishing the needed infrastructure that makes scientific discovery possible.

Community involvement has served the NSF well over the years, as research supported by the NSF has had a tremendous impact. Many new products, procedures, and methods have accrued from NSF investments in basic research, research performed over many years and not always predetermined toward a specific application. Society, unaware for the most part of how basic research impacts daily life, enjoys many benefits from NSF investments. These benefits include products such as Google, the favorite internet search engine; magnetic resonance imaging, MRI, used widely to detect cancer and internal tissue damage; geographic information systems, used by businesses, police departments, governments and others to respond to natural disasters, reduce crime, provide better services to customers; and many others.

The NSF investments have enabled the U.S. to build a scientific infrastructure second to none, facilitated revolutionary research that pushes the frontiers of knowledge, and laid the groundwork for innovation that has been important to the U.S. economy and a high quality of life. Thank you.

[Written statement by Samuel M. Rankin III follows:]

Testimony of
Samuel M. Rankin, III
Before the
House Commerce, Justice, Science and Related Agencies
Appropriations Subcommittee
Congressman Alan B. Mollohan, Chairman
Congressman Frank R. Wolf, Ranking Member
March 3, 2009

The National Science Foundation (NSF) is the only federal agency that supports basic research across all fields of science and engineering and all levels of science and engineering education. Although the agency's annual budget represents approximately 4 percent of the total federal budget for research and development, it provides nearly half of the support for non-medical basic research at colleges and universities. The main source of federal support for basic research at colleges and universities in the fields of mathematics, the social sciences, non-medical biology, and computer science comes from the NSF as well as over 40% of support in the physical sciences, engineering, and the environmental sciences. Through the directorate of Education and Human Resources, the NSF supports activities that ensure a diverse, competitive, and globally engaged science, technology, engineering, and mathematics workforce.

NSF invests over 90% of its budget directly to support research at colleges and universities, in all 50 states. This support reaches over 2000 institutions and nearly 200,000 researchers, postdoctoral fellows, trainees, teachers, and students every year. NSF receives well over 44,000 grant proposals each year, making over 11,000 awards, mostly to individual investigators at colleges and universities, and other public and private institutions. Through its merit review process, NSF identifies the best ideas and the people to develop these ideas, who through their work advance the frontiers of knowledge in science and engineering.

There are seven research directorates at NSF. Most of the funds for research are allocated to investigators through these directorates. Research proposals are received as a response to solicitations issued by disciplinary divisions within directorates and NSF offices or an investigator can submit an unsolicited proposal. In either case, the proposal goes through a merit review process which assesses the intellectual merit of the proposed project and the broader impacts of the project.

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THE GATHERING STORM

Mr. MOLLOHAN. Thank you, Dr. Rankin. Dr. Fisk, this morning we had testimony from Dr. Cicerone that indicated quite positively that NASA science was a science of equal quality of any of the sciences that are included in the competitiveness agenda, or that were recommended in The Gathering Storm Report. He indicated with not much other explanation that the reason for NASA being left out was that the Report was developed quickly. There has been a bipartisan effort to double the funding for NSF, NIST, and the DOE Office of Science. Should NASA science receive commensurate increases?

Mr. FISK. Yes. It would be good to do that. And I think you should always treat NASA science in the context of the space program as a whole, too. I mean, we should not lose sight of the fact that science is the foundation on which the Space Program is built. And so we also have to recognize the lack of adequate funding that the Space Program has received at the same time. You remember that on many occasions, and when I testified to this Committee earlier, when I was on the Space Studies Board we kept pointing out that NASA is asked to do too much with too little. And so there is a correction to the Space Program that is required. But in terms of the science that is in NASA, it is as important, and if we judge as a nation that we are to increase the scientific investments that we make, which is very much in our nation's future, then NASA science deserves to be there with everyone else. We can argue whether it is a factor of two or a factor of whatever you like, but the increases are required. Because we cannot, we are not accomplishing today what we could accomplish in the NASA science program.

Mr. MOLLOHAN. And as you allude, that should not be a zero sum game within NASA funding. NASA funding overall would be——

Mr. FISK. That is correct. I think it is important that it is not a zero sum game within NASA or within the NASA science disciplines. I mean, it is not a matter that you take from one and give to another. It is a matter of recognizing the importance of this scientific activity to the nation and supporting it in such a way that it contributes what it needs to contribute to the national endeavor.

Mr. MOLLOHAN. NASA science includes a wide range of science disciplines, including Earth science, astrophysics, planetary science, solar terrestrial physics, microgravity, and life sciences, as well as astronaut health. As you look at the current funding for NASA, are these different fields in relative balance? And if NASA science receives increases, should the disciplines receive them in the ratios as they are funded today?

Mr. FISK. No, I do not think so. Let me give you a fairly complicated answer to that, if you give me just a moment to talk about it.

Let us take planetary, astrophysics, solar terrestrial physics. They had planned their programs on a larger amount of money than they are now receiving. I mean, they were in the past, in the nineties and others, tracking the growth in non-defense discretionary spending. And then that was curtailed when NASA was forced to make decisions about keeping the Shuttle flying, and building the rocket to go to the moon within their limited budget. But there is an opportunity to do so much more and important things in those programs.

The other two programs that you mentioned, Earth science and life science and microgravity. Those programs have suffered far more disproportionately compared to the other science disciplines over that same time interval. In the case of Earth science, let us sort of review the bidding there. In the late eighties, early nineties, NASA embarked on a major program in Earth science—the Earth Observing System, Mission to Planet Earth, to really provide a comprehensive set of satellite observations of what the future of the planet would be, to make policy decisions on. In the mid nineties, a decision was made to curtail that program within NASA and transfer the main observing of Earth to NOAA and the NPOESS. And NPOESS, as you know, has been a major national embarrassment, a disaster. It is overbudget and it is not performing according to spec. And the climate measurements are hanging on by a thread, there.

And then at the same time, the Earth science program, starting in about 2000 within NASA began a serious decline to where as it is now essentially a $500 million per year short of what it was even in 2000, within the NASA budget. So you now have an Earth science program for the country and a climate monitoring system for the country which is inadequate to meet the national need to understand the climate and what we are doing to it. We are dependent upon three aging satellites that were left over from the original Earth Observing System. They are still operating, but they are well beyond their design life. And there are very few other research missions that are underway. So that is a program that has suffered disproportionately separate from the space science.

In the case of life science, in many ways it is an even more egregious case. We refer to the life science and microgravity science within NASA as NASA committed scientific genocide. It essentially destroyed a community that it was planning to use, in microgravity in particular and life science to a lesser extent. We are not really planning to use the space station and that was the community for the U.S. activities. And that community was dependent on the space station that, and the grants program, and the research program that went with it. And so that is a community and a program that has suffered even more strongly than Earth science.

So if I rank these things, astrophysics, solar terrestrial physics, planetary, they need support. They need to grow. There are many, there are things that they need to do, they are planning to do. They need to be put back on a slope that they were on, which was the basis for the program that they were anticipating. In the case of Earth science, we have a national need to restore that program so we get what we need. In the case of life science and microgravity it is a decision we should make as a country as to whether or not we really are anticipating long duration human space flight, in which case we had better do the basic research necessary to do so.

Mr. MOLLOHAN. Thank you, doctor. Dr. Rankin, following the Rising Above the Gathering Storm Report there has been a bipartisan effort to double the budgets of NSF, NIST, and DOE Office of Science. What effect is this having on NSF programs, and what are your expectations for the impact of the $3 billion provided in the American Recovery and Reinvestment Act?

Mr. RANKIN. Well when these bills, like the American Competes Act were first passed, I think everyone was very excited about the statement that NSF funding should be doubled over the next ten years. However, a lot of us remembered that we also had a doubling bill in, I think, fiscal year 2002 that was supposed to double NSF's budget from 2003 to 2007. And I do not think we ever even started. So in the last few years we actually have not gotten, even though things looked good up to the final game, in the end much of the increase that we were anticipating along the way. So we have not had a chance to actually think about how it would be if we doubled the budget until now when we have received this $3 billion all of a sudden.

I know one thing that the money, the $3 billion input into NSF, has done, is certainly build up the excitement and the morale, not only in the scientific community but actually, I think, at NSF as well. I think it will be an effort for the NSF to get this money out the door but I believe they can. I think most of the pressure will be more at the administrative end of getting the grants out the door than actually the program officers deciding who gets the grants. Because giving grants is a positive action rather than a negative one. When you are turning someone down it is a lot harder to turn someone down than it is to actually give a grant.

So given that they have all this money I think there will be a lot of new people coming into the pipeline, which will be good. I think there will be a number of young people that will be able to enter the grant pipeline through this funding that previously were doing good enough research but because of the funding levels were not supported.

So I believe overall this is going to be very, very important for science funded by the NSF and the scientific community. I believe a lot of good research will come out of this. My only concern about all this is what happens when this money goes away in the next few years? Will we be able to fund these folks that are in the pipeline, will we be able to fund them continually if they are doing good enough research?

Mr. MOLLOHAN. I am sure members want to know more about that, and will follow up in other questioning. Mr. Wolf?

Mr. WOLF. If we had given science all the money we gave AIG, can you imagine how they would be doing? Is there anyone who is mentioned to be head of NASA? Are there any names circulating that you are hearing?

Mr. FISK. All I know I read on NASA Watch or something like that. No, it is, I mean there are a number of newspaper stories. But I have no data on.

NASA ADMINISTRATOR

Mr. WOLF. Does it hurt NASA? The fact that there is not an administrator ready to come up.

Mr. FISK. I think it does. I mean, we are all very excited about the major policy shifts that are happening in our country at the moment. There are certainly many things going on at the moment.

And NASA needs to be at the table when these decisions are being made, and when, frankly, when the money is being passed out.

Mr. WOLF. Right.

Mr. FISK. And the person who is running NASA at the moment, the Acting Administrator, is a very capable person, it is Chris Scolese. But he is not the Administrator, and that is not the same.

Mr. WOLF. How serious is the competition from China? And we had asked the question earlier in the day, would it make an impact if China beat us back to the moon? And what are the ramifications with regard to China and space, and their military use of lasers?

Mr. FISK. In the case of China, I mean, I think what we should avoid, let me put it this way. Let us not repeat the Cold War and have some sort of a race to someplace we have already been. I do think there must be an opportunity here. We live in a globalized world that most, so many things are manufactured in China that we buy, and so on.

Mr. WOLF. Too many.

Mr. FISK. So it is a very different world than we used to live in. And somewhere within that globalized world there must be an opportunity for the United States to be a strategic leader in all of space activities, and to somehow include other nations, other space faring nations in the activities in such a way that all of us benefit, and it is not a Cold War, zero sum, we win, you lose sort of activity. That would be my preference, if we could do that.

Mr. WOLF. Well, that may be a little difficult with China.

Mr. FISK. It may.

Mr. WOLF. Yes.

Mr. FISK. It may.

Mr. WOLF. Without getting into the reasons. But I mean, a lot of China's technology they now have because they spied on us and so it is different with other countries. But what are the concerns with regard to the funding, or the decrease of funding, with regard to aeronautics? It seems to me that we are falling behind, or are we falling behind? And what has the impact been on the failure to fund aeronautics to the degree that many think it should be funded, with regard to NASA. What does that mean with regard to jobs, technology, keeping ahead, America?

Mr. FISK. You know, like any good university professor I will answer a question on any subject, including ones I do not know that much about. But let us——

Mr. WOLF. Well aeronautics, I mean, NASA is, that is the word. It is not just, that is pretty important.

Mr. FISK. Well I am just, I am trying.

Mr. WOLF. Unless we are going to shut down the Jet Propulsion Laboratory out in Pasadena and doing some of those things. Aeronautics is really important for the nation, and important for jobs and everything else.

Mr. FISK. Yes, I am going to get there. But here is what has happened in the space agency over the last decade or so, or eight years or so. You, NASA, was directed to go build a rocket to go back to the moon and was not ever given the money necessary to do that. And so you have within the budget all of these sacrifices that were made. Somebody made a decision. You can argue whether it was the right decision or not. But the consequence as, as we mentioned, life science and microgravity, gone. Or really, reduced. Aeronautics, a fraction of what it was when the vision was first announced. I mean, back in 2004, 2005. And there are consequences for those kinds of budget cuts. You do not do the things that the agency was charged to do, which is to help with the research necessary to have a competitive aeronautics industry in the United States. That was its job. And you cannot do it at one-quarter of the budget, which is basically where the budget for aeronautics went from back in the early part of 2000 or so to where it is now.

Now I think everyone was delighted who cares about the aeronautics program within NASA that it was included in the stimulus bill. And it is my recollection it was a $150 million increase in aeronautics, which in effect doubles the research budget of the aeronautics program of NASA. It is a huge impact. It will be a very similar question to the NSF question. Was that a blip? Or is that a reset? If it is a reset, then there is an opportunity to bring the aeronautics program back to what it should be.

Mr. WOLF. Well I was, I should not do this but I am going to do it anyway. If you look at the long term numbers, the money just is not going to be there. And it is unfortunate. Our entitlements are eating up the spending. I had mentioned to the witness earlier today that there is a movie out which I will get you a copy called IOUSA, put out by David Walker, who was head of GAO. I think in the year 2030 every dollar of taxpayer money that comes in will go for Medicare, Medicaid, social security, and interest on the debt. Nothing for cancer research, nothing for NSF, nothing for research on autism, on Alzheimer's, nothing on education, on math or science.

So the nation I want it to be, I have always supported the sciences. I think it is a job creation. I think it is an opportunity. I think America ought to be, but you know, it is the, the reality of it is unless there is a dramatic change by this institution and by the governing authorities it will not be there because it almost cannot be there. China holds one out of every ten of our dollars. And Hilary Clinton went over to China and was literally with a tin cup begging the Chinese to buy our paper, and yet not raising the issue of human rights and religious freedom. Because there is great pressure that we need China to buy our paper. So I am not sure it is going to be there.

The other thing, and maybe you can just comment, and Mr. Rankin I will get you in the second round. I think space is exciting. I can remember, you know, John Glenn and Shepard, and we all knew. When they went up we all knew who they were. We would stop where they were. In the classroom the teacher would have the television on. I would just challenge, on the last space shuttle, to name the names of the astronauts. And I would venture to guess that some could. You could. Most people would not even know who they were. And I think there has been something missing. So hopefully the next Administrator will be somebody who will be aggressive, can lay out the excitement and the importance whether it be on aeronautics, earth science, space, whereby. And I think do what President Kennedy did. And maybe here is where I will differ with you, that America will be competitive and we will do everything we can, and we will work to be number one wherever it may be. Because if we are not number one, probably the Chinese will be number one. And they are using their laser technology and others for things that are not very good for the world.

So I think that is part of the problem. We just have not really, you know, it is not like Glenn and Shepard. And do you have any comments?

Mr. FISK. You know, I think there is, you are right that the excitement of the sixties is not being repeated. But I think the thing we should never lose sight of is that so much has happened in the space program since the sixties, and so on. We have created a space program that basically is part of our national future, part of our national infrastructure. I mean, we are completely dependent upon space as a nation. Our military requires space. Our economy is very dependent upon, the globalization of the world is dependent upon space. These are all issues that have happened while we were thinking about the astronauts. But meanwhile we have created a space endeavor in this country which is broadly based and extremely important to both our economy and our national future. And that is the space program we need to recognize today.

Now, just so you do not misunderstand me about competition with the Chinese. I am a great believer that the United States should lead by example and in cooperation. By leading by example means we had better be the best.

Mr. WOLF. I agree. And in closing, not a question, I saw a figure that we had 95,000 people in the space program, government employees and contractors. And China had over 200,000. If those numbers are accurate, and I am going to ask my staff to check it out and we will put them in the record, that is very bad for our country. I thank you for your testimony.

Mr. MOLLOHAN. Thank you, Mr. Wolf. This is a good opportunity to state the Committee policy about calling on witnesses lest the audience, let alone members of the Committee, think that I have any bias toward our fine minority brethren on the Committee. We call upon members in order of seniority up until the time the hearing starts, and then in the order of members' arrival after that. And so in following that policy, which we follow and I think most Subcommittees follow, Mr. Bonner.

Mr. BONNER. Thank you, Mr. Chairman. As the newest member of the Subcommittee, and the most junior member of the Subcommittee, I appreciate this opportunity. It pays to get here earlier. As Chairman Serrano will note, when I was on his Subcommittee last year I tried to get to the hearings early and often so that I could have this opportunity. I appreciate it. I will be brief.

I asked the previous witness earlier today a question and I would like to pick your brains as well. And Mr. Wolf alluded to the fact that we all remember, or those of us old enough to, some of our guests today are too young to, but we remember sitting around our TV sets and literally stopping what we were doing to watch as NASA answered President Kennedy's challenge in the earlier 1960's. And yet, today we seen distressing numbers about interest in young people with math and science. What are we missing? What do we need to do? At what age do we need to prick the curiosity of young minds? And what role can NASA specifically play in helping to challenge young people to think beyond the current market opportunities?

SCIENCE EDUCATION

Mr. FISK. I am sure you are going to weigh in on this one as well, I hope. The, let us take NASA. I mean, you are absolutely right that we remember the astronauts, we remember John Glenn. And of course I am, I suspect I am older than you are because Sputnik to me was the thing that got me going in the world here, and challenged me to a, go into science and engineering, and the American response to it, obviously.

Now, it is very hard to reproduce those kinds of singular events. I mean, the world was, we were in the middle of a Cold War. The Russians were challenging us on all sorts of fronts. This was considered to be a challenge of significance. And we responded as a country and people were excited about doing that. I mean, like many people of my age, I remember being called in by my guidance counselor and being told, "You can add and you can subtract. You need to be, your country needs you, you need to be an engineer." And I said, "Well, I thought I wanted to be a scientist." He said, "Well, that is probably as good." But in any event.

Now we cannot reproduce that. But I think, with the space program, there are three things that space is supposed to do for you, I think. One is the inspiration. It is that same inspiration that says we do challenging things in space. We make exciting discoveries in space. And it can mean not just astronauts. It can be rovers on Mars and it can be the Hubble Space Telescope, and a variety of other thing which our technically literate generation has great appreciation for. We, in fact, even note in the space business that the younger generation is actually, seems at times to be more excited about the technology, you know, rovers and things, than they are about astronauts. And it has to do with the fact that in their everyday lives they experience through their computers and their iPhones and other things, vicariously all sorts of pleasures. And they can imagine being there with the rovers themselves.

NASA only has to be successful to do that. It has to do things. The second one is more direct. All the products of NASA need to get into the K through 12. I mean, they need to, the teachers need to have access to this. They have to be able to use them in the classroom in the inspirational way.

And the third one is more focused on the aerospace workforce, which is NASA has a very important role to play in the education of the aerospace workforce. Now, here you catch them later in life. You catch them when they are in college, and when they are in grad school. And you train the next generation of the truly technical people that we are going to depend upon for our space program, and we use NASA, NASA resources, NASA supported universities to be able to do that.

Mr. RANKIN. I will just speak a little bit about the education issue. I think that kids are very, at least little kids that I have seen, are pretty inquisitive. And somehow we knock a lot of that out of them by the time we move them through school. Mathematics, for example, is something that kids need and all of us need to a certain extent. It is a discovery kind of thing, but I do not believe in school that they see it that way. A lot of math is taught by rote, or, this is the way you do it rather than working with kids to let them discover things.

I think the best situations, or at least the times I have seen, where there is success with kids learning elementary level mathematics is when they are doing some discovery along with some rote learning. You do have to have some automaticity—this is a word that means you should be able to multiply, for example, two by three and get six. I mean, you ought to be able to do that. But on the other hand, that is not the only thing you want to do. And if that is all you practice all the time, your multiplication algorithms, for example, then you are probably not going to like math very much. But if you understand how math can be valuable to you, even in your young adult life, you will start paying attention to math and find value in it.

And I think one of the things that may keep kids from going into mathematics and science is that they do not realize that in order to get to science you have to know some mathematics, a basic level of mathematics. If you do not know this, and if you don't figure this out until the ninth grade, then you have no chance of going into science or mathematics. So I think getting kids interested in math early on is important.

Another way that we can help show this importance, not only though, but there are also lots of other discoveries that are made through science and mathematics. I believe the more that we can promulgate information about these discoveries and how science is involved, everyday things, for example the cell phone, or your computer, going on the internet, is important. It is science and mathematics. Yet, how many people really know this? And so, if we had a campaign to put out this information, and I think the NSF is starting to think about how to put out more information about some of the discoveries that are made under NSF funding, this is a way to help the general public understand that there is something good for society in funding science.

Mr. BONNER. Mr. Chairman, I know I do not have time for another question. But to close with Dr. Rankin's point. I have a thirteen-year-old daughter and an eleven-year-old son. And I can assure you that if they thought every time they wished for a Blackberry, or a cell phone, or a new video game, that that technology was a product of NASA or NSF, or one of the other, I think it would renew their interest in math and science and help their ailing father try to help them be better math and science students. Thank you.

Mr. MOLLOHAN. Thank you, Mr. Bonner. Mr. Aderholt.

PRICE OF NASA MISSIONS

Mr. ADERHOLT. Thank you, Mr. Chairman. It is good to be here with you and our guests here today. Thank you for being here. Much of the cost that is associated with NASA missions seem to be tied up in costs associated with getting a science payload launched into the orbit. Some estimates put those costs as high as $10,000 per pound. The question is, how do the current costs of launching science payloads into space limit our nation's scientific agenda? And how would a significant reduction in the cost of launching payloads into space benefit NASA's science programs?

Mr. FISK. There are a couple of answers to that. One of the principle cost growths in recent years has been on the launch vehicle side. And that is driving costs, making it less possible to do, to use your science budget to get science. There are fewer missions you can fly within the budget envelope you are stuck with.

It is true, though, that the launch vehicle cost as a fraction of the mission cost is still reasonably low. In other words, the science satellite itself, and the data analysis and so forth that will come from it, is still a much bigger cost. In other words, we do not launch cheap missions on top of rockets. So the percentage cost saving that you can get for the total mission, simply by reducing the launch cost, is not insignificant but it is not major because of the cost of the satellite itself.

But you say, "Well, why are launch vehicles costs going up?" Well, they are going up in large part because we do not fly very often. The launch vehicles providers are forced to maintain a infrastructure for the occasional purchase of a launch vehicle. And that makes the cost per vehicle much higher than it would be if you had a lot of launch vehicles being purchased. So, you know, to some extent, you know, the limitations on the science budget of NASA have reduced the number of missions, which have in turn driven up the cost of the launch vehicles, which has made you reduce the missions even a little more. Because the cost of the launch vehicle is not just putting that vehicle together. The cost of that launch vehicle also includes maintaining all of the infrastructure to be able to build the launch vehicle. If you purchase only one a year, you still had to maintain the factory and the workers that were capable of doing this thing. And therefore, your cost per vehicle has been going steadily up.

Mr. ADERHOLT. Do you think there are basic science and engineering questions that remain unanswered regarding space transportation? If so, do you think that implementing a basic scientific research program focused on making progress on the unanswered science questions associated with space transportation is appropriate for the federal government?

Mr. FISK. The rocket equation is the rocket equation. We are not going, we are not going to necessarily invest something new to do something. I mean, in some ways our rockets look a lot like the ones Wernher von Braun built in the forties. It is always possible to make improvements in, particularly in the reliability of rockets, and the cost savings associated with them. That is worth an investment because you do not have a space program unless you can get to space. And this is true on the military side, it is true on the NASA side. And so we are dependent upon the reliability of our launch vehicles, the costs of our launch vehicles. And, the lower we can make this, the more reliable we can make this, the better the nation is in so many regards.

And so that is worthy of a federal investment. I do not think that we should expect some magic breakthrough that comes from that. It will be an incremental improvement on launch vehicles that we have been building systematically since the beginning of the space program. Because of the, the basic technology is there. You can make it better, you can make it more reliable, and we should.

Mr. ADERHOLT. Okay. Thank you, Mr. Chairman.

Mr. MOLLOHAN. Thank you, Mr. Aderholt. Mr. Culberson.

Mr. CULBERSON. Thank you, Mr. Chairman. Thank you very much for your testimony. I am, as everyone on this Committee is, committed to doing all that we can to support the sciences, the National Science Foundation, NASA. If it were possible to split out just that piece of the stimulus, Mr. Chairman, that pumped money into NASA and the National Science Foundation I would happily have been able to vote for that part.

This testimony you are giving us is vitally important, and I wanted to zero in on two areas and get your comments. Number one, of course I agree completely with you that the Bush administration did not adequately fund the goals that they set for NASA. They set this ambitious agenda out there and then did not provide the money through the Office of Management and Budget. That was a bad problem. That coupled with the, what appeared to be some unrealistic cost estimates on a lot of major flagship missions that inevitably they had cost overruns because the initial estimates were inadequate, did not help. And in particular the, I wanted to first of all ask about an area of astronomy, for example.

DECADAL SURVEY

The decadal survey, which is the, as we all know, the survey done every ten years among scientists to tell the Congress which projects are the most important and which should be funded, apparently the, I am looking at an article from the Journal of Science, January 30, this year, the top priority from the 1991 survey, an infrared satellite observatory called Spitzer did not fly until August 2003. And virtually all of the cost estimates in the 2001 survey turned out to be too low. Quoting from the article, “So this time officials at the U.S. National Science Foundation, NASA, and the Department of Energy want the numbers to stick.” Are you familiar, either one of you, with what the agencies are doing to try to make sure that we do not lose some of these missions and they get realistic cost estimates that the Subcommittee and the Congress can rely on?

Mr. FISK. Yes, I am familiar because of my previous role as the Space Studies Board Chair. The agency, remember the decadal surveys are an academy document. They are generated by the National Research Council.

Mr. CULBERSON. Right. But used by this Committee and the Congress——

Mr. FISK. Absolutely.

Mr. CULBERSON [continuing]. And the agencies, as we should.

Mr. FISK. Absolutely. But in terms——

Mr. CULBERSON. As a roadmap.

Mr. FISK. But the cost estimation, NASA provides numbers but the academy has got to do a better job than it did in previous surveys in making sure those numbers are realistic. So in the Astro 2010, which is the next astronomy survey, just now starting, the Academy will in fact engage official cost estimation processes, industrial models, for being able to predict more reliably what the costs are going to be. It is not easy. Because you are always dealing with a mission that really is not that well defined. I mean, no one has agreed to go ahead with this mission. It is basically something that is intended to be started within the decade. And so, the planning process is early. And that gets you almost inherently into trouble.

But we, it should be possible to actually bracket more effectively the costs than was done in previous surveys. There was the most egregious case, as you noticed, the astronomy survey, in 2001.

Mr. CULBERSON. Yeah, the Webb, the Webb Telescope.

Mr. FISK. That is correct.

Mr. CULBERSON. Which is a great instrument, and it needs to fly. But the cost overruns are just unbelievable. It has gone from I think, what is it, about $1 billion to maybe about $4.5 billion before it is through.

Mr. FISK. Yeah.

Mr. CULBERSON. And, you know, and an example also for the Subcommittee of a project that is at the very top of the decadal survey list that has hit every, I believe, cost estimate, hit every target, met every goal, is the Space Interferometry Mission out of Jet Propulsion Laboratory, the SIM Mission, where they, which is so vital to allow the next generation of space telescope to identify habitable planets. We have got to fly it. Yet, you know, Griffin and NASA kept trying to chop it. This Subcommittee restored it and I thank the Chairman and the Ranking Member for their help with it.

We are committed to making sure that the decadal survey missions get flown. We do want to make sure, the Subcommittee, I know, wants to make sure that we are getting realistic cost estimates so we know that the, we will do whatever we can to avoid these cost overruns. In fact, the Science article points out that the National Science Foundation is going to hire cost contractors who will independently estimate the cost of the various proposals. It says Marcia Rieke, an astronomer at the University of Arizona, so you basically have an outside check and balance on some of these.

Mr. FISK. It is not the NSF. It is the National Research Council, I think.

Mr. CULBERSON. That prepares the decadal survey?

Mr. FISK. Yes.

Mr. CULBERSON. That actually prepares the decadal survey.

Mr. FISK. Yes.

Mr. CULBERSON. We, I think I would also like to ask, finally, Mr. Chairman, your advice and guidance as I am going to move forward. I volunteered earlier in the previous hearing and I am going to put this together as a proposal for the whole Subcommittee to look at. A mechanism for recommending to the Congress and the Appropriations Committee a level of funding for the National Science Foundation, NASA Science, and maybe we need to include NIH at some point. But start with the sciences, NASA Science, NSF. It seems to be we ought to have an outside panel of experts, scientists, unrelated to, with absolutely no political influence outside of the administration, to give us a budget recommendation. Because I frankly do not trust OMB. I do not care who is the President. They, the bureaucrats at OMB are not scientists and they are driven by forces other than science. And they do not, I do not even know if they even pay attention to the decadal survey. And it would be nice to have as a Subcommittee an objective, realistic estimate of what the National Science Foundation and Science at NASA actually needs from an outside source that we would then use as a starting point for the work of this Subcommittee. Thank you, Mr. Chairman.

Mr. MOLLOHAN. Thank you, Mr. Culberson. We are pleased to welcome back to the Subcommittee Mr. Serrano who was its Ranking Member I think for four years, or six years?

Mr. SERRANO. Six years.

Mr. MOLLOHAN. Six years, three congresses. Served the Committee extremely well during a period when Mr. Wolf was the Chairman of the Subcommittee.

Mr. SERRANO. And Mr. Rogers.

Mr. MOLLOHAN. And Mr. Rogers. Thank you. Welcome to the Subcommittee, José. Mr. Serrano.

KIDS INTERESTED IN SCIENCE

Mr. SERRANO. Thank you, Mr. Chairman. Thank you so much, and it is a pleasure to be back. Joseph Michael Acaba, Joe Acaba. So this is in answer to Mr. Wolf's comments that we do not know who the astronauts are any longer. If you have an agenda like I do, you do know that name. Because a couple of years ago I sat next to you, Mr. Chairman, and I said to the NASA Administrator, I said, "You know, we live in a society, for good or bad, where ethnic and racial pride and community pride are very much a part of who we are. And how nice it would be for children in Puerto Rico and in the Puerto Rican community throughout the fifty states to see someone who identifies with that community." So maybe the Committee had something to do with it. Joe Acaba is assigned to the crew of STS–119, as Mission Specialist Educator, tentatively scheduled to launch on March 12, 2009 to deliver the final set of solar arrays to the International Space Station. Just remember that name. Anyway.

What I wanted to talk about was brought up by a lot of members. And that is this whole issue of how to get young people interested in the sciences. And the exciting way to do it, I think, in many ways, is through space travel. And I thank NASA, in absentia, for the fact that they work in the Bronx, New York and the schools and do a lot of work in this area. But the public discourse on space programs tends to take a tone of days gone by, as if the public's interest in space technology had waned since the days of Apollo. I would be interested to hear your thoughts on how NASA's space and science programs might go about reestablishing, or repositioning their programs, in a way that remains relevant to everyday Americans. And are there ways to further bridge the gap in terms of how space science relates to issues such as climate change and green technology? The short answer may be that we have gotten so used to spaceships taking off that we no longer think it is a big deal. And Mr. Wolf is correct, when we were younger this was a big issue. And you remember these names, and you really rooted for them. So is there a way to bring that feeling back? Is there a way to get Americans to pay more attention and be interested in it? And is there a way to begin to tie in to space travel with all the other sciences and the research that has to be done?

Mr. FISK. I think there is. It is NASA and our national leaders, and all that must participate in this process. I live in Michigan. I live in the middle of the country, right? And now Ann Arbor is a special place. But five miles out of town there are normal people. And if you ask them about NASA they say, "Oh, are they not going to the moon? Did we not do that?" You know. "Why are we spending money on that?" And they do not recognize how much of their everyday lives are in fact touched by space. And we need very much to somehow do that. To communicate that thought. I mean, there are the famous stories about, you know, I think it was a congressman who said to someone from the Weather Service. You know, why do I need the satellites? I get my forecast from the——

Mr. MOLLOHAN. Now, come on. Come on. That was not a congressman.

Mr. FISK. It is an urban myth.

Mr. MOLLOHAN. That was not a congressman.

Mr. FISK. It is an urban myth. But——

Mr. SERRANO. It is the same congressman who asked me about currency from Puerto Rico one day.

Mr. FISK. But the point I think is that we do not recognize how pervasive civil space is. Now, the issue of climate change, which is of serious concern to the entire world, we will understand climate change and what it is going to be and what humans are doing to it, and what we should be adapting to, and what we should be worrying about, only through space. I mean, period. I mean, it is a flat out statement. You need the global perspective of space to be able to do that. So everyday lives are going to be influenced. And we have to keep telling people. It is your space program that is doing this thing. It is not an accident that this is happening. I mean, this is not something that is different from your space program. This is what your space program is doing. It is doing climate change. It is creating new technologies. It is answering basic human questions. It is doing all these things.

That is why the science program at NASA actually has great importance. Because it touches the lives far more directly than simply going to space with humans, which is very important to the future of the country, and all those good things. But the everyday lives are more touched by the science program of NASA than any other program.

Mr. SERRANO. So is it that it has lost its novelty?

Mr. FISK. I think there is some of that.

Mr. SERRANO. Or we have gotten used to such technological successes that we do not think it is that important anymore?

Mr. FISK. I think we do not recognize where things come from. I mean, and I think that is all our faults. Because we do not remind people that is what it is that is happening. And it is, you know, essentially your government supporting an activity which is benefitting your lives, and we should talk about those things. But I also think the agency has its faults here as well. Because in an effort to command the resources necessary to do the things that they think they were directed to do, like human space flight, they have put more of their emphasis on that than, and not recognized that in fact the other parts of the program are what are really impacting people.

Mr. SERRANO. Yes.

Mr. RANKIN. I would just say that, looking at young people today they have different ideas about things. And I do not know that it is actually reasonable to think that they are going to go back to the 1960's and have the same feeling we had when we shot the space rocket up in the atmosphere. But there are lots of things that are affecting everyone. And I think it will affect younger people even more so because they are just now coming through life. Climate change is one thing that has already been mentioned. But energy conservation is another, and clean water is another. And it seems to me that these are the kinds of things that people could get interested in, especially if they see how these things could possibly affect them in negative ways if we do not look at these areas and think about how to improve our situations. So I think I would suggest that we try to find the things that are happening today that might be on the minds of young people. A lot of young people these days are interested in conservation and ecology and things like that. And I think we can take advantage of these kinds of things, and there is science behind all of these. You know, you can always find science and mathematics in all of these endeavors.

Mr. SERRANO. I would agree, and that was my point. To get them interested in the space program by understanding what role it plays in the other issues that they are interested in now. Thank you, Mr. Chairman.

Mr. MOLLOHAN. Thank you, Mr. Serrano. Mr. Schiff.

Mr. SCHIFF. Thank you, Mr. Chairman. I was going to raise a similar point. But before I do, Mr. Chairman, I saw you on the NBC Nightly News last night. Apropos of your original comments today, there was segment on the changing face of America. It focused on a Latino family in Wisconsin. But in profiling the changing face of America they showed your face, and Nydia Velazquez. Did you happen to see that?

Mr. SERRANO. No, I did not.

NASA SCIENCE

Mr. SCHIFF. Yeah, NBC Nightly News, Brian Williams. You know, Dr. Fisk, I appreciate very much your testimony today. And the case you make for NASA science. I am not sure we are diagnosing the problem correctly, though. And, because I have wrestled with this, too, with the view that NASA is a luxury that we cannot afford in difficult times. I think there is the same fascination of when we were kids with the manned space flight. I mean, I see it reflected in different ways. I see it reflected in the billions of hits on the website when the Mars rover lands and starts roving. I see an interest, you know, not only here but around the world. But somehow that interest seems to get lost between there and this Capitol, and the White House.

And I think there are two scientific questions that are really the preeminent questions that not only the American people but everyone has. Probably the first is, what can science do to improve my health and the health of my family? That is probably the most pressing scientific question that people have. But only second to that, I think, is the question are we alone? And when I, you know, read your testimony, Dr. Fisk, and I read statements like this. "We have observed the remnant radiation from the Big Bang that began our universe. We have found that the universe has continued to expand, driven by a force that we do not yet understand. We have discovered that there is a matter in the universe, a lot of it which we cannot yet observe. We have seen galaxies forming at the beginning of the universe and stars forming in our own galaxy. We have discovered planets around other stars, many of them. So many that it is ever more likely that there are other earths and perhaps other civilizations comparable to our own."

How can you fail to be fascinated by that? And I do not know what we need to do differently. But people are inherently interested in that question. And there is no more popular person I bring to my district than an astronaut. And the interest is out there. You know, I labor, like we all do on this Committee, to justify our NASA expenditures in other ways, and tell people, "Well, your cell phone technology came from NASA. A lot of improvements in medicine came from NASA." But I think that the, you know, the fascination with space and with the fact we may not be alone is the most powerful driver. You know, it is the old kind of exploring frontier ethic. And I think we need to find a way to make sure that is not lost between there and here.

Mr. FISK. I could not agree more. There are so many dimensions to that problem from my thinking. I have this belief that the United States chooses to be a great nation and has a reason for that. That is our destiny. And I considered it one of the responsibilities of a great nation to try and answer some of these basic human questions. So there is that dimension to it.

This is innate in us. We have been asking those questions in some form since the beginning of civilization. I mean, this is a basic set of human questions we try and answer. And you can fascinate people. I mean, even those people in Ann Arbor and outside of Ann Arbor I can fascinate with those kinds of conversations. And you say, "Now why is it that that does not come through somehow when we get closer to the Treasury?"

I do not know. We do not have some great spokesman, particularly. You know? I mean, every now and then I wish Carl Sagan were still alive. We need people who somehow personify this. It is not just an esoteric thing. There is a face that goes with this when we think about this. And we have not created those kinds of spokespersons in our society that people can identify with when they ask the questions. I mean, they can be fascinated by the discussion but they want to have the discussion with a person. And that may be in some ways what we are missing more than anything else.

PLANETARY DECADAL SURVEY

Mr. SCHIFF. Let me ask you just a follow up on a very small subset of space science issues. NASA recently decided on the sequencing for the outer planet flagship missions. Europa, followed by Titan. That order, I think, is consistent with the planetary decadal survey, which has always ranked Europa as the highest priority. Nonetheless there has been this continuing debate, at least in the past. Are we settled now on Europa? Can we go forward and not have to keep revisiting this?

Mr. FISK. Yes, the answer is I think so. That is a question you probably ought to direct to NASA. I mean, the debate has been going on. Europa was highest in the decadal. Enceladus, you know, came from behind and was looking promising. And but I, all I know on that subject is what I have been told. And I think the debate has been settled but I, yeah.

Mr. CULBERSON. They just completed the survey.

Mr. FISK. Right.

Mr. CULBERSON. They picked Europa.

Mr. SCHIFF. Thank you, Mr. Chairman.

Mr. FISK. Good choice, by the way.

Mr. CULBERSON. Yes.

Mr. MOLLOHAN. Thank you, Mr. Schiff. Mr. Honda.

FINANCING SCIENCE AT AGENCIES

Mr. HONDA. Thank you, Mr. Chairman. And welcome, and pleased to hear your thoughts and your testimony. It is refreshing. And I know that a lot of comments have been made about costs and money and comparing one thing to the other. But I think that we have to look at the history of how we finance all this stuff and how we finance it and how we budget it is really a reflection of our values. And we have a chance now to look at it again. And in that context, and perhaps this question was asked before I got here, but in the context of the change in the possibility of looking at rearranging some of our programs and priorities, what would be your recommendation as to reshaping, revamping, refocusing on this whole area that we look at when we think about NASA, NOAA, and the other agencies?

Mr. FISK. The, Congressman Wolf asked me earlier about the future and the budgets and so forth, and whether the country could afford it. I guess I have a point of view, too, that says we invest in science and technology because the only hope for the future of the country, and for our civilization, and for our economy, is the investments in science and technology were made so that we will in fact benefit from it. Our economy will expand, our civilization will be better off, and we will survive as a planet and a civilization.

And so the investment is not an option. It is essential to the future. And the question is how much investment do you need? I think we all recognize that the investment that has been made to date is inadequate. And that the growth in our economy and the growth in our standard of living and so forth will require a larger investment in science and technology. And then you sort of work your way down. I mean, the NSF had a plan that says, you know, they need to double. And they are well on the way to that, I think, with the budgets and so forth. And NASA is the same, the space program is equally as essential to our future in the broadest sense, not just the science portion. And the science portion within it, in the sense it is of growing importance to the space program because it is the part of the space program which touches people's lives more directly these days than other parts. Aeronautics as well.

And so you basically say, what you want to have happen is this reset. The stimulus package was not a blip, but it was a reset. And in the case of NASA it was under what it should have been to be even a blip. It needs to be a bigger blip, and then it needs to be a reset so that there is a continuation of this investment. And I think that is what you have accomplished with your stimulus package. You have corrected the problem from the past, the under-investment. But now there has to be a continuity that extends that into the future so because science is not done in a year. I mean, the investment is not going to be done at the end of October 2010. The question is, is how do you go forward from that making the investment necessary to have the economy grow, the civilization be better off? And that is what we need to do?

Mr. HONDA. The opportunity to do this is here. And having spoken with the previous witness the question came up, with all these agencies dealing with science and research, whether it is earth science, oceanographic, NOAA, space, they are all related. And it does not seem that we should be dividing them up and trying to see which is a priority but rather see how they work together so that the information comes together in a sensible format so that we say we are getting the most bang for our bucks. And then also, you know, commercializing it in different ways.

But looking at our budget in the future, is there a group out there that can look at this approach and recommend a way to fund our programs adequately so that we can be aligned and on time on the core mission of each agency, and also provide the information necessary to, you know, move things along.

Mr. FISK. I think it is going to vary somewhat from discipline to discipline. In disciplines that are contained in an agency, astronomy from space is contained in NASA. There is astronomy in the NSF but it is more research and ground based astronomy. They need to work together, but to some extent. So when the decadal survey, which was mentioned earlier, is done by the Academy, it plans for everybody. It plans for NASA, it plans for the NSF, it plans for the Department of Energy, which participates in the nation's astronomy program. And that gives you an answer to what you should do in that particular discipline.

Earth science is always the outlier because it touches so many different agencies. We have a decadal survey in earth science, which is a National Academy document. But it deals primarily with NASA and NOAA. It does not deal with the Department of Energy, it does not deal with USGS particularly, or only to some extent, and so on. And so you need to, and the government has done coordination in the past on these issues, usually done through the Office of the OSTP, the Science Advisor. And so to some extent the coordination on earth science, so that all the agencies play in a program that is able to do the nation's things. That has to be, I think, one of the most effective things is to ask the President's Science Advisor to do as we have in the past, to give you that kind of coordination. And essentially present to you, as the Appropriations people, this is what is required for this agency to play in the national science program. That was actually done in the eighties and the nineties, and has been done less so recently.

Mr. HONDA. Right. I think that we were trying to starve them, or we were not adequately funding them, so.

Mr. FISK. Yes.

Mr. HONDA. To answer a question on a personal basis about interest in science and space. I thought about that really for a moment. And it seems to me that we probably have, this is not a slam against TV or anything else like that, or light pollution. But it seemed to me that ancient people had done a lot of staring at the skies and wondering. And through generations it seems to me that they came up with the idea of astronomy, math, science, timing, and things like that, even came up with the concept of zero. Perhaps we do not look in the skies enough to touch that part of our humanness of wondering. Are we alone?

Mr. FISK. Yes. I think there is a lot to be said for that.

Mr. HONDA. Yes. Well, thank you very much for your testimony.

OFFICE OF SCIENCE

Mr. MOLLOHAN. Thank you, Mr. Honda. Mr. Rankin, Dr. Rankin, following longstanding practice the Office of Science at the Department of Energy funds high energy physics and nuclear physics, although the current focus of research in these fields is basic research addressing fundamental questions such as the nature of matter and the fundamental forces of nature. Is this appropriate? And does this placement of an area of fundamental research in an agency other than NSF result in an overemphasis in this area? Or any other concerns?

Mr. RANKIN. I personally do not see a concern with it. I mean, this kind of thing happens all the time. I know when I was a program officer for a while at AFOSR and I used to collaborate with folks at NSF in funding folks to do research. So I actually look at it as a positive thing, that it is a way of leveraging money. If both agencies have support for the same area of research then it is a way that they can collaborate or share funding of various projects. And in that sense make their money go further, and have more people involved in the research.

I would suggest that program officers should try to collaborate and let each know what the other is doing and who is being funded. Sometimes this happens on the program officer level automatically. I mean back when, as I said, when I was at AFOSR I just worked with another program officer over at NSF and we knew that we had certain people that were applying to both agencies. So we decided to split the cost and that way he could use half his money for something else and I could use my half for another investigator.

Mr. MOLLOHAN. Thank you. Dr. Fisk, what is the status of space biology and space physical sciences at NASA?

Mr. FISK. The space biology, I mean, both space biology, the physical sciences and the microgravity environment, those sorts of things, they were of course transferred into the Exploration Office, Exploration Systems Mission Directorate, ESMD. It has not been a happy time for them there because that office's primary responsibility has been to build the Aries launch vehicle, and Orion, and so on. And there has been a systematic scale back. I mean, that was my earlier comment. It was only a few years ago that during one September basically all the grant program was canceled and 500 scientists, post docs, or graduate students and undergraduates were laid off. And so there has been a tremendous scale back that occurred in those disciplines.

Would I have made the same decision? I mean, it is hard, it is hard to say. I mean, you cannot get to space, you do not need these programs. But you need a rocket to get to space. You go through that argument that says, well, building the rocket is the priority when you have limited funding. But the consequence is your long term future.

First of all, why are you going to space if you are not planning to use it in some ways, whether it is in the microgravity environment, or if you are not planning to have humans be able to live and work in space? And that requires some discoveries in basic research and biology. This is not, we do not know enough today to say that the human can go into space for long duration space flight in a radiation environment, which is what would be required if we are going to the moon, going to Mars, going someplace else. We do not know enough to do that today. And it will be basic research which gives us that and that program has suffered more than any other science discipline within NASA.

Mr. MOLLOHAN. Well, and without those programs or that study at some point you would not know the challenges, and you would not know how to deal with them. Is this a matter of timing? Are these issues that can be put off to another day because——

Mr. FISK. They can to some extent. We have obviously been to the moon and we can get there. We know we can get there and you can spend three days, or whatever it is. And there is a partial gravity on the moon if we are wandering around there. We are not so clear about the radiation environment that will also be an issue on the moon, and so on. So you are going to need this.

But I think there is another thing that just is not recognized in this. You do not turn science disciplines on and off like a faucet. And basically, particularly in the life science and the microgravity, or life science in particular and microgravity to a somewhat less extent, the best and the brightest in that field have choices as to what they do. If you are a space, if you are doing space biology you may be also working for the NIH on basic human health issues. If you are doing microgravity in space you may be a material scientist that is working with the NSF or the Department of Defense. So NASA turns you off. And in fact, in some cases, NASA not only turned people off they forced them to lay off their graduate students precipitously. Those folks are not coming back. They said enough of this.

Mr. MOLLOHAN. What is the consequence of that?

Mr. FISK. I sense if we are really serious about doing this research and you want to turn this back on because we need the answers, we are going to have to rebuild again. You are going to have to go out and convince people. I mean, to some extent, some of these people treat this like Lucy and the football, you know? You teed me up once and you, and this is not a new event for NASA. They have had this community go up and down over time. You put the football there and you go to kick it, and you pull it away. They are not Charlie Brown. They are not going to come back and try again. And I think, you know, the first thing that is going to have to happen when somebody says yes we really needed that answer, is somebody is going to proactively have to, and it is going to be a sales job. They are going to have to say, okay, why are you serious this time that you were not serious the last time, or the time before that?

Mr. MOLLOHAN. Well, what is your recommendation in this regard? And what is the timing?

Mr. FISK. I think the damage is done to some extent. I guess I am troubled by the fact that we built the Space Station and we do not plan to use it. And, you know, the number of NASA experiments on the Space Station is very small. Basically, the Europeans and the Japanese are having a wonderful time, and we are doing less and less. We do not have a community that does this thing. And so, it seems to me that was a bad choice.

BUDGETARY DECISIONS

Mr. MOLLOHAN. Is that driven by a budgetary decisions alone?

Mr. FISK. Strictly budgetary, it is basically, we cannot afford it. And we have ended up in a somewhat silly position. Basically we have to fly the Shuttle to finish the Space Station because of our international commitments. The Shuttle money is coming out of the rest of the NASA program and we cannot afford to use the Space Station. And you say, gee, tell me again why that was? If you tell NASA you have $17 billion, and these are all the things you have to do, and this is your highest priority, you know, namely replace the Shuttle, what else are you going to do? I mean, you are going to make these choices. But the, there are long term consequences for those near term decisions. And it would be wise if somebody, especially if we are trying to redress some of this money that is available, that somebody says, hey, maybe it is not too late. Call that guy up, you know, that you fired and laid off and don't have him——

Mr. MOLLOHAN. Well, if you were to do that, there would have to be corresponding decisions you would have to make with regard to station and access to station.

Mr. FISK. Right.

Mr. MOLLOHAN. What would those be?

Mr. FISK. Well, we continue to fly the shuttle until 2010. And we have resupply contracts now in place. There are two competitors who have been awarded contracts to fly autonomous ELVs to the space station, not the shuttle, for resupply.

We are going to be dependent upon the Russians as it is now. And while the gap still exists until an American launch vehicle is available, we are not abandoning the space station.

Mr. MOLLOHAN. No, we're not.

Mr. FISK. We are just not using it.

Mr. MOLLOHAN. We are not abandoning it. But transportation is a real limiting issue here, is it not? Would you be able to turn on microgravity and space biology research, as you suggested, before being able to access the station in ways other than——

Mr. FISK. Yes.

Mr. MOLLOHAN [continuing]. Resupply?

Mr. FISK. I don't think that is so much the issue. There is an issue of down mass, which is the question of bringing things back from. You know, if you do experiments on the station you may want to bring something back. And so you would have to make sure that the resupply that you have is safe.

But there are going to be people on the station. And those people can do this research if there are payloads. And you will have to ask, you know, can I get—make sure I get the payloads there? But I—and, you know, you really have to ask NASA the question. But my understanding is that the resupply that is being—has been contracted for has the capability to take experiments up there, not just stuff, you know, supplies.

Mr. MOLLOHAN. Okay, thank you.

Dr. Rankin, in the President's budget, he speaks of encouraging exploratory and high-risk research through NSF. First, let me ask you in the peer review process is there a tendency at NSF toward conservatism?

Mr. RANKIN. Well, I think that can happen.

Mr. MOLLOHAN. Is it typical? Is it a defining characteristic of the peer review process?

Mr. RANKIN. I don't know that I would say it is a characteristic. I think—I have heard NIH folks mention this quite a bit more than I have folks from NSF. But I think it is natural in times when money is tight that people want to make sure they spend the money well. Although that doesn't mean that they actually do all the time. But I think the peer review process has worked pretty well at NSF.

Over 180 Nobel Prize winners have at one time in their career received NSF money. I have mentioned some of the innovations that have come from NSF Support, and there are many other innovations. This means that at least the process is picking good people working on good science.

I think if you are talking about doing transformative research, I think we have to make—I think it would be good if the NSF director would create a culture of that within the agency. And I think it should start with going down to the directorates. This is where it is going to happen and with the program officers. Maybe there has to be some training of program officers of how to work with the community to build this idea of transformative research. But I think it can be done.

Mr. MOLLOHAN. But it is not necessarily there now?

Mr. RANKIN. Well, yes, there has obviously been transformative research.

Mr. MOLLOHAN. No, there has been. But people are concerned about this. And they are talking about it, and——

Mr. RANKIN. Well, I think because there is so much money now that is coming in. I think generally the scientific community is worried that we are sort of stuck in a rut and that we need to move forward with new discoveries.

I think what the rhetoric is about is that we want to create an environment where we are looking at these high-risk projects. But calculate the risk and see if they are worthwhile. If the projects are worthwhile and we can pick the right people to work on these, then I think it is probably something we ought to do.

Mr. MOLLOHAN. If it becomes a policy directive so to speak and money is associated with it, you are suggesting that the adjustment to the extent NSF would have to make an adjustment through the peer review process wouldn't be something that——

Mr. RANKIN. I think, they could—I think they should have information sessions where they talk to reviewers, but I think program officers need to go through this as well, because the program officers in the end make the final judgement. They take the advice of the panels or the reviewers, but in the end they make a recommendation based on these reviews. But there may be other things that program officers know about that causes them to make a different kind of decision.

Mr. MOLLOHAN. Thank you. Mr. Wolf.

Mr. WOLF. I'll pass, Mr. Chairman.

Mr. MOLLOHAN. Mr. Aderholt. I'm sorry, Mr. Culberson yes. I thought you left.

FUNDING LEVELS

Mr. CULBERSON. I had a phone call, excuse me. Sorry. Thank you. Thank you very much.

Let me if I could ask both of the witnesses what you would think of—just food for thought. In order to provide stability, predictability at the funding levels for National Science Foundation, which is the root of much of the problem we have had, if the—because I am going to put together a proposal for this Subcommittee to make a serious effort at adopting into law that we remove—take OMB out of the loop when it comes to making funding recommendations for the National Science Foundation and NASA for that matter. And put that in the hands of an independent board of experts. What about the National Science Board? I think Dr. Ray Bowen is the Chairman and former President of Texas A&M.

Mr. RANKIN. Not now. Steven Bearing.

Mr. CULBERSON. Isn't that—who is the President?

Mr. RANKIN. Steve Bearing is the current Chair.

Mr. CULBERSON. Frank Bowen was the Chairman?

Mr. RANKIN. I think maybe a while back.

Mr. CULBERSON. Okay. Who is the Chairman now?

Mr. RANKIN. Steven Bearing.

Mr. CULBERSON. Okay.

Mr. RANKIN. Steven Bearing.

Mr. CULBERSON. Okay. What would you think about that? Let them make the budget recommendation to us on the funding level that is necessary for the National Science Foundation and NASA to do the job that they are entrusted with to have a panel like the National Science Board make that budget recommendation to the Appropriations Committee formally instead of the Office of Management and Budget.

Mr. RANKIN. I don't know. I haven't thought about that. The Science board already has oversight of the NSF.

Mr. CULBERSON. Yeah, policy.

Mr. RANKIN. The policy of the NSF.

Mr. CULBERSON. I just frankly get sick and tired of OMB short-sticking NASA. I get tired of them short-sticking NSF over the years. We all know the Bush Administration did not give adequate funding to NASA or the National Science Foundation. The Bush

Administration loaded up NASA with a lot of projects then did not give them the money.

Mr. RANKIN. Well——

Mr. CULBERSON. And then it was up to this Committee to try to find a way to make it up. And it was tough.

Mr. RANKIN. Well I don't know—I mean personally I would like to see science—I will talk about the NSF. I would like to see the NSF, and you can say this about all science, funded in a way that we know what to expect year over year.

I mean, we talk about doubling these different agencies, doubling the NSF.

Mr. CULBERSON. Right.

Mr. RANKIN. But the fact of the matter is that this is tough to do. And on the other hand if you do do it, it gives you a sense that you have accomplished the job.

Mr. CULBERSON. Yeah.

Mr. RANKIN. And, therefore, you stop. If you look at the example with NIH, they doubled from 1998 to 2003. Then bang, they stopped, NIH got no more money.

Mr. CULBERSON. Right. We have got a vote going on. I want to make sure to submit any comments or questions. If I could then would you both agree then the most important message to leave with the Chairman of this Committee is that we find a way to provide stable, predictable funding levels to NSF?

Mr. RANKIN. On an uptake.

Mr. CULBERSON. Stable and predictable, I think I know how to help you do that. Thank you.

Thank you, Mr. Chairman. Thank you for your—thank you all for being here. And thanks for having this hearing by the way. Thank you.

Mr. MOLLOHAN. Well being able to vote and return and keep the hearing going is a benefit of having a hearing room——

Mr. FISK. I am impressed.

MATHEMATICS IN THE UNITED STATES

Mr. MOLLOHAN [continuing]. In the Capitol. You trade off. Use the small space for that.

Dr. Rankin, as the only mathematician who is appearing this week actually as a witness, please give us a brief picture of the overall support environment for mathematics in the United States.

Mr. RANKIN. Well, the NSF is the major supporter of mathematics in the U.S. It represents about 47.6 percent of overall funding. However, if you look at just the federal funding for basic research in mathematics in universities and colleges, then the NSF represents about 60 percent of that funding. The remainder of the funding for mathematics comes from the Department of Defense, it is about 17.9 percent, the Department of Energy, 18.4 percent, and NIH is about 16.1 percent.

These numbers have changed over the years. It used to be that NSF was clearly 50 percent or more of the funding for mathematics. Then DOD took a big slice and then DOE. Over the last ten years there has been a change. And also the fact that NIH is now becoming more of a player.

There are quite a few mathematicians now that get funding out of NIH, usually working with a biomedical scientist. And there is this program through the Division of Mathematical Sciences at NSF and the National Institutes for General Medical Sciences where they—I think the way it works is that NSF puts in a dollar and NIGMS puts in two dollars.

Mr. MOLLOHAN. Thank you.

Mr. Aderholt.

NASA CIVIL SERVANT SCIENTISTS

Mr. ADERHOLT. Thank you, Mr. Chairman. It is my understanding that under NASA's implementation of full cost accounting, scientists working as NASA's civil servants are increasingly being asked to seek funding to cover the full costs of their salaries. Yet NASA scientists are civil servants. And furthermore they are not always permitted to compete for funds external to NASA, such as those made available by the National Science Foundation.

This situation creates anxiety and stress among current NASA civil servant scientists. And at a time when the average age of the agency's scientific workforce is increasing, this does not establish NASA as an attractive career option for the next generation of our nation's biggest scientists.

The question would be science makes advances through competition of ideas. And NASA civil servants as well the agency benefit from scientific competition. But from your perspective does it make sense that NASA scientists who are civil servants also compete for their salary? Just your—both of your thoughts on that.

Mr. FISK. I think what is important is that they compete. And this is not a new issue. I mean, you want a—you want to have science done by the people that are best able to do it. And I think that it is important that NASA scientists. And they have for the tradition of, you know, the whole history of the space science program dating back, you know, as far as I know. I mean, NASA science people had to submit proposals for research support. The only difference is whether their salaries were in it or not. I mean, any other costs that they had associated with this had to be won competitively in competition with the universities and all the other people.

So that part I think is all right. And I also think to some extent having their salaries in this is not—is not an issue. I think—and, you know, this is a question where you really ought have the NASA person here. I can't—I still—even though I haven't been an associate administrator in decades, I still somehow think I answer questions for the agency.

But the—it seems to me that one of the most difficult parts in competition over the years was the overhead rates at centers, because it was not only scientists competing for their salaries. But then there was an overhead charge on that which was exorbitant compared to their competitors. And that was in part because not every NASA civil servant could win in competitive things. And yet they still had to be funded, and the centers had to be funded, and all these other things.

And I think, and I would encourage you to ask the NASA people this, that they have in fact corrected that situation where the overhead is now paid out of some general account some place. And the competition is now for salaries and other costs of doing the research.

And that is not an unreasonable place for NASA scientists to be, because actually they now even have a competitive advantage to the universities. Even though university overhead rates were lower than the center overhead rates, there are still overhead rates at the universities.

So the NASA scientists have the sort of competitive advantage if they are only being charged for the—for their salaries and their research. And that is a good trade I think in my judgement between asking them to not compete and asking, you know—and making sure their salaries are adequately covered.

But you are correct in one very important point. It is absolutely essential that we revitalize the NASA workforce.

Mr. ADERHOLT. Dr. Rankin, do you have anything else?

Mr. RANKIN. I didn't realize that these folks are employed by NASA but they have to apply for grants?

Mr. FISK. From NASA.

Mr. RANKIN. I didn't realize that went on. It doesn't strike me as a good situation. If they are employed by NASA, it seems to me that they should work for NASA. And if NASA wants to have them work on research, that seems like a good thing. I don't quite understand why they would apply for grant support if they are already paid by NASA.

Mr. ADERHOLT. Let us go back to the history as you were talking.

Mr. FISK. Well the—I mean one of the things that NASA has worried about it in its past, it worries about it less these days, is the relative balance between universities and NASA centers. And people—you know, it—when I was Associate Administrator, I considered it my job to make sure that that balance was correct, because we have to think not of just NASA centers when we think of the space program. We have to think of the infrastructure of the country to do space. And space science is done at universities and government labs, and it is done in certain kinds of industries some places and so on. And that is the entire thing.

And we need to create a system, which gets the maximum for the country out of this. Not just is it done in this center so let us look at the country as a whole. And one of the ways that that was maintained over the years was to have competition between the university scientists and the NASA scientists as to the support.

And the traditional model, until full-cost accounting was put into effect, was that the NASA scientist had to vie for grants to give them support beyond their salaries, just things they were going to do, things they were going to build.

And now with full-cost accounting, we went to the other extreme, which was not only their salaries with the overhead. And I think they are back to a system, which is just their salaries and their support.

And often I think it is a way for NASA headquarters to make sure that the country's best are applied to this, regardless of whether they are in a center or the university. And frankly I think that is healthy.

Mr. ADERHOLT. Why can't you have interchanging between the centers and the universities of personnel? It seems like that would be—I mean people do that all the time in other situations we see.

Mr. FISK. You are into—I mean, do you want to do IPAs or something?

Mr. ADERHOLT. Yeah, sure.

Mr. FISK. Yeah, but no. I mean, those are minor events. I mean, there is a whole cadre of scientists at Goddard and JPL. And JPL by the way has always done it this way with the salaries. I mean, JPL is an FFRDC. The salary support for the scientists at JPL is won by—as part of the JPL contract or through competitive grants and contracts. It is only the NASA civil service centers where this issue arises.

Mr. ADERHOLT. And JPL is a part of CalTech.

Mr. FISK. Yeah.

Mr. ADERHOLT. Thank you, Mr. Chairman.

SATELLITE MISSIONS

Mr. MOLLOHAN. The satellite missions are often done in cooperation with other nations and the Multinational European Space Agency. Is the U.S. contributing its fair share in these efforts? And how does the cooperation work in terms of sustaining U.S. science technology, engineering, and its leadership?

Mr. FISK. Again, it is a somewhat complicated answer. I mean, we talk about Earth science for example. Since we have let our capability in Earth science slip dramatically, it is very hard for us to be this leader that says let us get the world together, and figure out what is happening to the climate, and use the best of everyone's capabilities to do so.

So when you want to lead by example and in cooperation, you better make sure you are bringing something to the table that you are capable of. And in certain fields we are not.

In other fields we are such clear leaders, you know, planetary exploration, astrophysics. That when we cooperate, we do so because there is an advantage, a national advantage. We bring in some technologies from other countries and so forth. But there is a case where we are in some ways so far ahead that it is not—you know, our cooperation is important and it is good for scientific collaborations, good for our image, as a country, as a leader, and so on.

But let us—you can't have a discussion about international cooperation unless you want to have an ITAR discussion, because the number one impediment to any meaningful international collaboration in space is ITAR.

Now you can have missions where they do something and we do something. We share the data in the scientific literature. That is okay. But if we actually want to do something together, a spacecraft, you contribute, your nation contributes, we contribute, unless somebody fixes ITAR, it is not a workable system.

And so you have got competing national policies here. If we think it is in our interest as a country to collaborate and—on scientific issues, not military, scientific issues, then the ITAR rules have somehow got to change and become commensurate with what we are trying to do as a country.

Mr. MOLLOHAN. Have you thought about that enough to give us your opinion on how that should change?

Mr. FISK. Yeah. I mean, I will fall back on mine. I have an opinion on it. Like all good university professors I have an opinion on everything. I mean, one of the things that I would explore—I mean, there is a law first of all, which, you know, you will have to deal with here. But within the law as I understand it, there is a question of what is on the ITAR list? What is on the controlled list?

Even if you say we are going to have exactly the same law, I mean, somebody decides what is a controlled technology. And if we can make that restricted to things that are really essential for the national interest, you know, the national security as opposed to the kinds of stuff that is there now, which you can buy in the world anywhere in lots of cases.

Mr. MOLLOHAN. Those decision are based on fear for the national security.

Mr. FISK. Oh, no, they are not. I mean——

Mr. MOLLOHAN. Can you give it to me in an exact—off the top of your head?

Mr. FISK. The question is whether you can control technology. You would have to assume we had it and someone didn't. And yet in many cases the capabilities that are on the ITAR list can be purchased in other countries in even more capability than we have—you know, we are talking about electronics here. We are talking about basic kinds of things.

There have been—there have been hearings. And I was not part of them where, you know, some—there was someone as I recall in one of these, in a House hearing, someone came in and said, "I bought all these pieces in Radio Shack. And I put them in a satellite. And now they are an ITAR controlled item."

And so, you know, there is a silliness to the listed controlled technologies—it is comprehensive. It is too comprehensive. Somebody should simply go in and say, okay, tell me exactly what technologies we have to control in the interests of our national interests and take everything else off. I mean, that would be my simple solution.

Mr. MOLLOHAN. Okay, thank you. Dr. Fisk and Dr. Rankin, we want to thank you very much for appearing here today. We are in a series of votes. I think it has been a fine hearing. I think we learned a lot. And we especially appreciate each of you appearing and giving us the benefit of your expertise and answers to the questions. We look forward to seeing you again in the future. We have some questions submitted, which we would appreciate your answering them.

Mr. FISK. Sure.

Mr. MOLLOHAN. It won't be burdensome.

Mr. FISK. Sure.

Mr. MOLLOHAN. We appreciate the time that you have given us today.

Mr. FISK. Well thank you very much. I have enjoyed it immensely.

Mr. RANKIN. I wanted to also thank you for your efforts on behalf of the science community, the NSF in particular, in the stimulus bill and also in the fiscal year 2009 appropriations. Thank you very much.

Mr. MOLLOHAN. Well, thank you.

Mr. FISK. Thank you.

Responses for the Record

House Committee on Appropriations Subcommittee on Commerce, State, Justice and Related Agencies

Hearing on: The Place of NASA Science in the Overall Science Enterprise

March 3, 2009

Lennard A. Fisk
University of Michigan

Question 1:

Within the budget for Science at NASA there is support for building and operating satellites, maintaining data systems and a wide range of research ranging from numerical modeling and analysis of satellite data to laboratory and field observations, including aircraft and balloon measurements. What balance should there be in terms of funding for these different activities?

The activities that are listed in addition to the building of satellites are generally classified as mission-enabling activities. They enable NASA's basic mission of exploring and utilizing space through the launching of satellites.

When considering these mission-enabling activities, we need to ask whether there is a complete portfolio of activities. Are there new technologies being developed that will lead to new measurements and missions; is the future workforce being adequately trained; is the data from existing missions being fully utilized; are theories being developed and models built that allow us to understand the data, and decide what future measurements are required?

There is no simple formula that can be used to decide on the balance of these mission-enabling activities, since the portfolio of activities will vary by discipline. In the case of Earth science, there is a requirement for ground-truth established by field observations, in particular with aircraft. There are certain astronomical observations that can be made from balloons, the instruments for which provide technology demonstrations for future space instruments, and hands-on training for graduate students. Rather, the balance has to be established for each discipline, to ensure that all the mission-enabling activities required for NASA's mission for this discipline can be effectively achieved.

The National Research Council, at the request of Congress, is currently conducting a study to determine the metrics by which effective mission-enabling activities for each discipline of space and Earth science in NASA should be judged, and to evaluate the disciplines based upon these metrics. I am the Chair of this study committee. The report should be available in the fall.

<u>Question 2:</u>

How would you characterize NASA's role in science, technology, engineering, and mathematics education, including K-16 and teacher training, and are there changes you would recommend?

NASA is an important contributor to science and engineering education at many different levels. Its accomplishments are inspirational and encourage K-12 students to pursue careers in science and engineering. Teachers are provided information and training that can make science education more interesting and relevant, and as a result more effective. There is also the training of the aerospace workforce in colleges and universities, through the use of hands-on projects.

The United States has a unique advanced education model – the research university. We train our advanced students in universities that actually conduct research in the development of new technologies and science, and as a result we have the best engineers and scientists in the world. NASA and the Department of Defense historically have been responsible for providing the research opportunities in aerospace to universities, thus facilitating the training that has created the nation's aerospace workforce. In recent years, however, NASA has reduced its support for universities participating in the development of space hardware. The result is that the hands-on training of the next generation of space scientists and engineers is no longer adequate. At the same time, the aerospace workforce is aging and needs revitalization.

The educational mission of NASA for K-12 will always be limited by the funding available. The national need for better science education is extensive; however, this activity is secondary or even tertiary to NASA's main mission of exploring and utilizing space. However, central to NASA's main mission, and one deserving of more support, is NASA's role in undergraduate and graduate education; the actual training of the next generation of the aerospace workforce.

WEDNESDAY, MARCH 4, 2009.

THE PLACE OF NOAA & NIST IN THE OVERALL SCIENCE ENTERPRISE

WITNESSES

DR. JAMES SERUM, PRESIDENT, SCITEK VENTURES
DR. SUSAN K. AVERY, PRESIDENT, DIRECTOR, WOODS HOLE OCEANOGRAPHIC INSTITUTE

OPENING STATEMENT BY CHAIRMAN MOLLOHAN

Mr. MOLLOHAN. The hearing will come to order.

Good afternoon, Dr. Avery, Dr. Serum. Yesterday we received an overview of science in the United States and examined the role of NASA and NSF in the overall science enterprise.

This afternoon, we will examine the role of two other research agencies under our jurisdiction, NOAA and NIST, both of which are included in the Department of Commerce.

Following the issuance of the report, Rising Above the Gathering Storm, there has been a bipartisan effort to double the fiscal year 2006 funding of NIST along with NSF and the Department of Energy Office of Science over a ten year period.

The stimulus funding provided in "The American Recovery and Reinvestment Act of 2009" increased fiscal year 2009 funding for NIST by roughly 70 percent while providing a roughly 20 percent boost to NOAA.

Looking forward, it is important for this Subcommittee to understand the relative roles and status of the different research agencies. We look forward to learning more from Dr. Avery about NOAA and from Dr. Serum about NIST.

We would like to welcome you to the hearing, letting you know that your written statement will made a part of the record and you can proceed with your testimony as you will.

But first, I would like to call upon the Ranking Member, Mr. Culberson, for any comments he might have.

Mr. CULBERSON. Thank you, Mr. Chairman.

I just want to say once again how much I appreciate the way you have structured these hearings. All of us on the Committee appreciate the outside perspective, the independent objective. Outside perspective is very important to us and we appreciate very much your being here today to help us in our effort to make sure the sciences are fully funded as they should be.

Thank you very much.

Mr. MOLLOHAN. Thank you, John.

Let us proceed with Dr. Serum.

Mr. SERUM. Uh-huh.

Mr. MOLLOHAN. Your written statement will be made a part of the record, please proceed as you like.

Mr. SERUM. Thank you, Chairman Mollohan and Ranking Member Wolf, for the opportunity to testify about the role of NIST in the overall science enterprise.

My name is James Serum and I am the President of SciTek Ventures, a science and technology consulting firm. I have been deeply engaged in developing and commercializing measurement technologies and applications for over 40 years.

I have been associated with NIST for the past ten years, serving first as a member of the National Research Council Assessment Panel for the NIST Chemistry Lab and since 2004 as an elected member of NIST's Visiting Committee on Advanced Technology, VCAT. I am currently the Chair of that federal advisory committee.

From my long association with NIST, I can tell you that NIST is a unique research agency and a critical element to this nation's scientific enterprise. NIST is the only federal agency that I am aware of that is specifically focused on promoting U.S. economic competitiveness. Unlike other government research agencies, the primary stakeholder of all NIST programs is industry.

Today I hope to show you that whether it is through technology research, the development of advanced precision measurements, or the creation of standards that NIST provides the tools essential to increase the productivity and efficiency of industry, accelerate the adoption of new technology, and enable fair trade.

Measurement science and standards are the foundation for technological innovation. The measurement science performed at NIST is often at the cutting edge of science, providing the foundation for many new technological innovations. This is important because if you cannot measure something, you cannot control it. And if you cannot control it, you cannot reliably manufacture it.

NIST's unique role is to advance measurements and standards so that the next innovation can be realized and commercialized. The impacts of NIST measurement science research are numerous.

For example, the work of one of NIST's Nobel Laureates, Dr. Jan Hall, was focused on the precise measurement of the wavelength or color of light. An unprecedented accuracy and precision of the technology pioneered by Dr. Hall has been the foundation upon which numerous technological advancements have been built, including the development of extremely accurate atomic clocks, increased capacity of fiberoptic communications, new methods to rapidly diagnose disease, and ways to identify trace chemical species in the environment.

NIST research also provides industry with critical tools that help overcome such challenges as cleaner and renewable sources of energy.

NIST measurements have led to improvements in fuel cell design, helping large and small companies such as auto makers, Dupont, and Plug Power to improve the efficiency and durability of fuel cells for zero carbon emission vehicles.

Another critical element to NIST's role is the development of standards which provide the common language in commerce. NIST standards enable U.S. manufacturers to design and build products to one standard or a set of standards with an outcome of increasing their competitiveness in the world market and facilitating global trade.

In addition to NIST's role in measurement science and standards, the Technology Innovation Program, TIP, and the Manufacturing Extension Partnership, MEP, provide critical support and services to America's competitive backbone, its small businesses. These help to foster collaboration across diverse technology partners and to develop transformational technologies.

TIP created by "America Competes Act" provides NIST with the capability to overcome the barriers to successful innovation by investing in high risk, high reward science that address critical national needs.

This year, TIP addressed the nation's critical need for improvement in the nation's physical infrastructure. I am convinced that TIP will be a key part of the federal portfolio that helps accelerate American innovation.

The Manufacturing Extension Partnership, MEP, is a unique partnering program of manufacturers, states, and federal government to increase the competitiveness of U.S. small manufacturers. The MEP network bridges the productivity gap for small manufacturers by identifying opportunities for growth and profitability by encouraging technology development and providing services that reduce manufacturer's bottom line expenses, increase efficiencies, and build capacity.

These are just a few examples of the important role that NIST plays in the overall science enterprise. Founded on precise measurements, NIST programs have a high impact and benefit to entire industries by enabling innovation.

I applaud the Subcommittee on its leadership in writing the fiscal year 2009 appropriations bill that provides NIST with the resources outlined by the "Competes Act."

I would urge Congress to continue to show a strong commitment to NIST and not overlook the important and essential role it plays in our nation's scientific enterprise.

Again, thank you for the opportunity to testify today. I look forward to answering your questions.

Mr. MOLLOHAN. Thank you, Dr. Serum.

[Written statement by James W. Serum, Scitek Ventures follows:]

Testimony

of

James W. Serum
Scitek Ventures

Before the
House of Representatives
Committee on Appropriations
Subcommittee on Commerce, Justice, and Science

"The Role of the National Institute of Standards and Technology in the Overall Science Enterprise"

Thank you Chairman Mollohan, Ranking Member Wolf, and members of the House Subcommittee on Commerce, Justice, and Science for the opportunity to testify before you today on the role of NIST in the overall science enterprise.

My name is James W. Serum. I am the President of Scitek Ventures, a science and technology consulting firm focused on helping young companies commercialize innovative ideas and early stage technology. I have been deeply engaged in developing and commercializing measurement technologies and applications for over 40 years, having spent most of my career with Hewlett Packard Company. Upon retirement in 1999, I founded an information technology business, Viaken Systems Inc. and a technology consulting firm, Scitek Ventures LLC, both focused on measurement systems. I have been associated with NIST for almost 11 years, having served first as a member of the National Research Council Assessment Panel for the Chemical Science and Technology Laboratory (CSTL), and, since 2004, as an elected member of NIST's Visiting Committee on Advanced Technology (VCAT). I am currently the chair of that organization.

From my long association with NIST I can tell you that NIST is a unique research agency that is a critical element of this Nation's scientific enterprise especially as it provides the tools necessary to accelerate technological innovation and competitiveness. In fact NIST is the only Federal Research agency I can think of that is specifically focused on promoting U.S. economic competitiveness, and unlike other government research agencies the primary stakeholder of all NIST programs is industry. Today I hope to show you that whether it is through technology research, the development of advanced precision measurements, or the creation of standards that promote quality and enhance efficiency, NIST provides the tools essential to increase the productivity and efficiency of industry, accelerate the adoption of new technology, and to enable fair trade.

Measurement science and standards, the foundation of technological innovation

The core of NIST's scientific impact flows from the NIST laboratories, and their continued focus on measurement science and standards. The NIST Laboratories continue to be the premier measurement and standards laboratory in the world with the highest level of expertise. The measurement science performed at NIST is often at the cutting edge of science providing the foundation to enable many new technical innovations. Like an extreme athlete - competing at the edge of human endurance, NIST's measurement science is focused at the extremes - measuring smaller objects or phenomena faster or more accurately than anyone else. This is important because if you can't measure something -- you can't control it. And if you can't control it - you can't *reliably* manufacture it. NIST's unique role is to advance measurements and standards so that the next innovation can be realized and commercialized.

The impacts of NIST measurement science research are numerous. Take for example the work of one of NIST's Nobel Laureates, Dr. Jan Hall who won the Nobel Prize in Physics in 2005. Dr. Hall's work was focused on the precise measurement of the wavelength (color) of light. The unprecedented accuracy and precision of the technology pioneered by Dr. Hall has been the foundation upon which numerous technological advancements have been built including the development of exquisitely accurate atomic clocks that have resulted in unprecedented improvements in navigation and positioning (GPS), increased capacity of fiber optic communications, new methods to rapidly diagnose disease, and ways to identify trace chemical species in the environment and complex industrial products.

The measurement science research at NIST also provides industry with the critical tools that will help the US overcome some of our most daunting challenges. For example in our Nation's effort to develop cleaner and renewable sources of Energy, measurement science at NIST is enabling new technological opportunities in everything from Green buildings to photovoltaics. In the area of fuel cells scientists at NIST's Center for Neutron Research recently have developed ways to use neutrons to make key observations of the interior of operating fuel cells. These measurements have led to improvements in fuel cell design and are being used by large and small companies such as General Motors, Chrysler, Dupont, and PlugPower to improve the efficiency and durability of fuel cells for zero carbon emission vehicles. A National Academy of Sciences report describes this NIST work as *"...a considerable achievement and one of the most significant analytical advances in the membrane fuel cell field realized in decades."*

In addition to performing research in measurement science, another critical element to NIST's role in innovation is its role in standards. Standards come in many forms. There are the SI units - for example the meter, kilogram, and second. There are also documentary standards like the formats that describe ways to store digital data for movies or music. In addition, there are standard reference data and materials. Standards provide technical definitions and guidelines for design and manufacturing. They serve as a common language, define quality and establish safety criteria. In the United States, standards are developed by private-sector organizations such as American National Standards Institute (ANSI), American Society of Mechanical Engineers (ASME) and many, many, more. These standards are used by industry and are frequently adopted by government agencies as a means of establishing regulatory requirements. They are vital to the economic health of many industries, and – more important – they help to ensure the health and safety of the American people and of citizens in countless nations around the world. One of the biggest impacts of NIST's role in standards comes in facilitating global trade. The Department of Commerce and NIST have a vital role in ensuring acceptance by other nations of U.S.-developed standards that incorporate technological advances and that meet changing industry, regulatory, and public safety needs. Enabling U.S. manufacturers to design and build to one standard or set of standards increases their competitiveness in the world market, which makes NIST efforts to assist U.S. standards developers in their negotiations with international and national standards organizations critical to the U.S. business community.

These are just a couple of examples of the impact of NIST's measurement science and standards can have. Again let me reemphasize that this work forms part of the foundation upon which innovation is built. NIST measurements and standards were integral to the successful development and adoption of virtually every one of the 20th century's greatest engineering achievements – including automobiles, aircraft, lasers, computers, and the internet. It is essential that NIST's role in innovation not be overlooked and that it receives the resources it needs to continue their significant contribution to the advancement of technology, measurement innovation and industrial competitiveness.

Catalyzing future technical advancement and strengthening America's manufacturing base

In addition to NIST's role in measurement science and standards, its Technology Innovation Program (TIP) and Manufacturing Extension Partnership (MEP) provide critical support and services to America's competitive backbone – its small businesses. Together these programs:

- Foster collaboration across diverse technology partners and fund small businesses and universities to incentivize the development of transformational technologies that address key national needs;
- And, provide services that strengthen and enhance the productivity of U.S. small manufacturers

The creation of the TIP program by the America COMPETES act provides NIST with the capability to overcome the barriers to successful innovation and disruptive technology development faced by the private sector and government that were identified in the seminal National Academies report *Rising Above the Gathering Storm*. TIP has already made a start to address some of the Nations key technology challenges. With its inaugural competition for funding in FY 2008, TIP addressed the nation's critical need for improvements in physical infrastructure. Specifically, TIP conducted a competition for high-risk, high-reward research addressing "Advanced Sensing Technologies for Infrastructure: Roads, Bridges, Highways and Water Systems." Outputs for the first Program year include the awarding of 9 cooperative agreements with 31 recipients, including 17 small or medium businesses, 11 universities and 3 local government laboratories in 12 states. These 9 awards have the potential to generate an additional $46 million in industry cost-share over 3-5 years. I feel that with appropriate and stable resources the new Technology Innovation Program will be a key part of the federal portfolio to accelerate American innovation by supporting transformational research in areas addressing critical national needs.

The Manufacturing Extension Partnership is one of NISTs better known programs. It is a unique program partnering manufacturers, states, and the federal government to provide a wide range of services strengthening U.S. small manufacturers. Currently MEP runs a network of 59 centers in 443 locations across the U.S. This network enables MEP to bridges the productivity gap for small manufacturers by identifying opportunities for growth and profitability, and encouraging technology deployment. MEP assistance enables manufacturers to streamline plant operations, create or retain jobs, develop new markets and products, and successfully compete in the global marketplace.

The MEP program has a strong history of measurably improving the productivity and competitiveness of Hollings MEP clients. The most recent (FY 2007) client reported impacts include:

- new sales of $5.60 billion,
- retained sales of $4.88 billion,
- client cost savings of $1.44 billion,
- new client investment in modernization of $2.19 billion,
- creation and retention of 57, 079 jobs, and
- 28,004 clients served.

MEP successfully provides the services that reduce manufacturers' bottom-line expenses, increase efficiencies and build capacity. I am confident that MEP will continue to improve the efficiency and growth of US small manufacturers positively impacting the employment and profitability of this important part of the U.S. economy.

From my long association with NIST I have seen year after year that NIST generates a high rate of return for investment in its programs. Whether through investment in its laboratories and user facilities where nineteen retrospective studies of economic impact show that, on average, NIST labs generated a benefit-to-cost ratio of 44:1 to the U.S. economy, or through programs like MEP that leverage less than $100 million dollars of federal investment into a nearly $300 million dollar program by teaming with industry, state , and local organizations to increase sales, reduce costs, and generate and save jobs for our nation's small manufacturers, NIST programs have a high impact and benefit entire industries or sectors of the economy.

If NIST is fully enabled it is sure to have dramatic near and long term impact--increasing the productivity and efficiency of US industry, promoting safe and fair commerce, and helping to ensure an economically, vigorous and competitive United States as we move to the future. Unfortunately Federal support for NIST has been falling relative to U.S. GDP and industry research for many decades. This means that even though technology has become more and more important to the U.S. economy, the federal infrastructural support that NIST provides has been severely challenged due to resource constraints. I applaud NIST scientists and engineers for their "can do" attitude and doing their utmost to address a growing list of challenges and needs with limited resources. I have been encouraged that the America COMPETES Act, intended to double the NIST budget in ten years, remains a priority of the Congress and the administration. I also applaud this Subcommittee on its leadership in writing a Fiscal Year 2009 appropriations bill for NIST that provides it with the resources outlined by COMPETES. I would urge Congress to continue to show a strong commitment to NIST and not to overlook the important and essential role it plays in our Nation's scientific enterprise.

Again thank you for the opportunity to testify today. I look forward to answering any of your questions.

Ms. AVERY. Good afternoon, Chairman Mollohan and members of the Subcommittee. Thank you for the opportunity to speak with you today about the National Oceanic and Atmospheric Administration.

My name is Susan Avery and I am President and Director, of Woods Hole Oceanographic Institute in Woods Hole, Massachusetts.

My primary message today is that NOAA is critical to our nation's research effort to understand our planet as an integrated system in which the ocean, atmosphere, and terrestrial environments interact in a highly complex fashion.

These are areas of inquiry that have both immediate and global implications for long-term social and economic well-being of all peoples and nations. As such, they require integrated, intellectual approaches and close collaboration among researchers across disciplines, agencies throughout our government, and governments around the world.

Both the ocean and the atmosphere are shared globally and we must have international cooperation to address such issues as natural hazards, environmental quality, collapsing fisheries, and adaptation to and mitigation of global climate change.

NOAA has proven its ability to pursue such cooperation in numerous ways over many decades. Especially notable in recent years was its key role in providing scientific expertise and data to the Inter-Governmental Panel on Climate Change. NOAA's climate modeling capability is considered one of the best in the world and its models helped form the basis for the IPCC reports.

In many ways, NOAA is unusual among our government's science agencies. It is a mission agency responsible for monitoring both the atmosphere and the ocean, from predicting hurricanes to protecting fisheries. It works to conserve and manage coastal resources and environments where 14 of our country's 20 largest urban areas are located and where more than half the population lives.

Additionally, however, NOAA funds scientific research. It not only forecasts weather, it seeks to understand and predict climate. In effect, it makes a science investment in order to develop unified modeling, understanding, and prediction across atmosphere, fresh water, and ocean ecosystems.

One example is so obvious that we tend more to ignore it or take it for granted and that is the National Weather Service. NOAA forecast warnings and the associated responses produce approximately $3 billion in savings during the typical hurricane season.

With respect to forecasting the impacts of short- to long-term climate variability, NOAA has been a leader in detecting, predicting, and understanding the effects of El Nino southern oscillation or ENSO, which occurs every three to seven years. The often severe results of such events can include drought or floods, colder or warmer than usual winters, more or fewer hurricanes and typhoons.

Research has estimated an ENSO forecast to benefit the decision making of U.S. agriculture between 500 and $900 million a year. These examples are a startling measure of NOAA's importance.

The annual economic return to the United States economy of the ENSO observing system is between 13 and 26 percent, more than double OMB's specified minimum rate of return for federal projects. Yet, consider the ENSO observing system spread out across the vast reaches of the southern Pacific Ocean is anchored by only 700 moored ocean buoys supplemented by free-drifting floats and ship-based observations.

By contrast, in Maryland and Virginia alone, there are 84 land-based weather stations. In short, a greater investment in NOAA's research operations and services, including its many academic and industrial research partners, could bring a commensurate increase in return on that investment. Again, broad collaboration is essential.

These examples illustrate the scope of NOAA's responsibilities to the nation encompassing ocean, land, and atmosphere and their connections and collective effect on our planetary environment and global society.

I want to emphasize that the extramural research conducted by NOAA and its partners is critical to the agency's own success.

Research leads to understanding that refines the models that improve prediction, that informs policy, and, therefore, helps determine the ultimate economic benefit. In short, it is essential that all of NOAA's operations and services be based on science.

In summary, my recommendation is simple. They echo those of Rising Above the Gathering Storm report. Given the breadth of its mission portfolio, the wide range of science needed to support that mission, and the ever increasing demand for its products and services, I believe certainly a doubling of NOAA's research budget is required to carry out its missions.

As things stand, the scope of NOAA's mission far exceeds the dollars devoted to it. The budget as yet does not allow for the establishment of the much needed National Climate Service. And additionally, many of NOAA's facilities and operations are partially paid for out of its research budget, shortchanging the various science and partnerships that support and inform those services and operations and that contribute so greatly to NOAA's national value.

In fact, the total research component of NOAA's 2009 budget request, $537 million, is only 14 percent of its total budget. That mismatch between funding for services and operations and funding for research can only in turn shortchange sound policy and decision support.

Increasing NOAA's research budget and recalibrating that balance will be in line with this Administration's determination to restore the voice of science to the collaborative formation of national environmental policy and improve decision making. This will be good for NOAA, good for science, and, most of all, beneficial for the nation.

Thank you.

Mr. MOLLOHAN. Thank you, Dr. Avery.

[Written statement by Dr. Susan K. Avery, President and Director, Woods Hole Oceanographic Institution follows:]

WOODS HOLE OCEANOGRAPHIC INSTITUTION

Hearing on How the Mission and Related Research of NOAA Contribute to
The National Science Program

Written Testimony
Presented to the Subcommittee on Commerce, Justice, Science and Related Agencies
Committee on Appropriations
United States House of Representatives

March 4, 2009

Dr. Susan K. Avery, President and Director
Woods Hole Oceanographic Institution

Good morning, Chairman Mollohan and members of the Subcommittee. Thank you for the opportunity to speak with you today about the National Oceanic and Atmospheric Administration and its important contributions to the social and economic well-being of our nation. My name is Susan Avery, and I am President and Director of Woods Hole Oceanographic Institution in Woods Hole, Massachusetts. We are the world's largest private non-profit marine research and higher education organization. We are scientists, engineers, mariners and students dedicated to understanding the ocean and its interaction with the Earth system, and to communicating this understanding for the benefit of society. My own research background includes studies of atmospheric circulation and precipitation, climate variability and water resources, and the development of new radar techniques and instruments for remote sensing. I am author or co-author of more than 80 peer-reviewed articles. I also have a keen interest in scientific literacy and the role of science in public policy.

My primary message today is that NOAA is critical to our nation's research effort to understand our planet as an integrated system in which the oceanic, atmospheric, and terrestrial environments interact in a highly complex fashion. I also wish to stress that these are not arcane scientific problems. They are areas of inquiry that have both immediate and global implications for long-term social and economic well-being of all peoples and nations. As such, they require integrated intellectual approaches and close collaboration among researchers across disciplines, agencies throughout our government, and governments around the world.

You are doubtless all familiar with the National Academies 2007 report, *Rising Above the Gathering Storm*, which eloquently detailed the central importance of science and engineering to the U.S. economy, and which called on our government to support and enhance the national science and technology enterprise. I wish to press the case that NOAA is integral to that enterprise, not only for our country but for all nations. Both the ocean and the atmosphere are shared globally, and we must have global cooperation to address such issues as ocean acidification, collapsing fisheries, and adaptation to and mitigation of global climate change. NOAA has proven its willingness and ability to pursue such cooperation in numerous ways over many decades. Especially notable in recent years was its key role in providing scientific expertise and data to the Intergovernmental Panel on Climate Change. NOAA's climate modeling capability is considered one of the best in the world, and its models formed the basis for the IPCC reports.

In many ways, NOAA is unusual among our government's science agencies. It is a mission agency responsible for monitoring both the atmosphere and the ocean, from predicting hurricanes to protecting fisheries. It works to conserve and manage coastal resources and environments, where 14 of our country's 20 largest urban areas are located and where more than half of our population lives. And it operates our National Weather Service. Additionally, however, NOAA funds scientific research in use-defined areas. It not only predicts weather, it seeks to understand and predict climate. In effect, it makes a science investment in order to understand connectivity in our whole-Earth system. It conducts and funds research to develop unified modeling, understanding, and prediction across atmospheric, fresh water, and ocean ecosystems. Put another way, it touches all of our lives.

One example is so obvious that we tend more and more to take it for granted—the National Weather Service. We plan our daily commutes and our annual vacations with an ear always tuned to the weather. Farmers sow and reap according to NOAA weather predictions. Commercial transportation and shipping, both on land and at sea, depend on accurate weather forecasting to get products to market in the most cost-efficient way possible. NOAA warns us of approaching hurricanes and blizzards and alerts us to levels of fire danger in our state and national parks and forests.

With respect to forecasting the impacts of short to long-term climate variability, NOAA has long been a leader in detecting, predicting, and understanding the effects of the El Niño-Southern Oscillation. ENSO, as it's known, occurs every three to seven years, when Pacific trade winds either weaken or reverse, blowing east instead of west, causing surface water in the eastern tropical Pacific to be warmer than usual and altering atmospheric circulation patterns with near-global impacts on climate. As one of the key partners in the decade-long Tropical Ocean Global Atmosphere (TOGA) research program ending in 1994, in which many WHOI scientists and engineers participated, NOAA helped to design—and today continues to maintain—the major components of the ENSO Observing System, which provides accurate wintertime forecasts up to a year in advance based on knowledge of El Niño and La Niña events. The often severe results of such events are well known—based on the region, they can include drought or floods, colder or warmer than usual winters, more or fewer hurricanes and typhoons. In the U.S., coastal storms alone cause more than 70%, or $7 billion, of natural disaster losses every year.

An El Niño event in 1997-98 is estimated to have caused an overall U.S. economic impact of approximately $25 billion. That was about $1.2 billion better than the impact of an event in 1981-82, attributed in part to better forecasts and the actions people took in response to mitigate damage. The annual economic return to the U.S. economy of the ENSO Observing System is between 13 and 26 percent, more than double OMB's specified minimum rate-of-return for Federal projects. The economic bottom line is truly eye-opening: best estimates are that nearly a third of our Gross Domestic Product, or $3 trillion, is either directly or indirectly affected by weather and climate. That is a simple but startling measure of NOAA's importance.

Yet, consider: the ENSO Observing System, spread out across the vast reaches of the southern Pacific Ocean, is anchored by only 70 moored ocean buoys, supplemented by free-drifting ARGO floats and ship-based observations. By contrast, in Maryland and Virginia alone, there are 84 land-based weather stations. Together with the Environmental Protection Agency, NOAA is playing a key role in the U.S.-led international effort to develop a Global Earth Observation System of Systems that would link together many thousands of weather stations, hundreds of ocean buoys and floats, and dozens of environmental satellites in order to provide the integrated data and research approach necessary for a great leap forward in forecasting accuracy. In short, a greater investment in NOAA's research, operations, and services, including its many academic and industrial research partners, could bring a commensurate increase in return on that investment. Again, broad collaboration is essential.

An example of how NOAA encourages collaboration to tackle issues of enormous socioeconomic importance is the agency's promotion of Regional Integrated Science and Assessment (RISA) programs, which reach out to stakeholders to incorporate more science into resources management in order to improve how communities, planners, managers, and end-users such as farmers and public utilities prepare for and adapt to a changing climate. By funding extramural research teams while requiring effective partnerships with other federal agencies, state and local governments, and the private sector, NOAA is helping our nation to deal with potentially devastating issues like the growing demand for and conflict over water resources in the West, the impacts of prolonged droughts, and coastal erosion. Here too, NOAA's influence is international—knowledge gained and improved forecasting models are freely shared with international colleagues. That intellectual generosity is serving to generate momentum in other countries to incorporate RISA-type activities in their own resource management efforts.

In fact, NOAA plays a key role in resource management, not only along our coasts but throughout the nation. An example is the National Integrated Drought Information System, which will provide a drought monitoring and forecasting system at federal, state, and local levels. When complete, this will be an interactive system that not only collects data and serves as a forum for stakeholders and policy-makers, but also provides tangibles like early warnings of impending drought, comparative information about risk and impact, and support for policy planning necessary to manage impacts, all based on scientific research either conducted by or funded by NOAA.

A robust scientific understanding is equally important to management of the nation's fisheries. Looking again at economic impacts, in 2006, the commercial fishing industry in the U.S. generated $103 billion in sales and $44 billion of income, and supported 1.5 million jobs. Recreational fishing generated $82 billion in sales, $25 billion of income and supported 534,000 jobs. In addition to its contribution to the nation's economy and food supply, both commercial and recreational fishing are strong elements of the traditional culture and social values of many coastal states and communities.

NOAA's National Marine Fisheries Services (NMFS) has responsibility for the management of fishing activity between the 3-mile and 200-mile limits of U.S. waters, and manages 230 commercial stocks via 47 different management plans administered by 8 regional Fishery Management Councils. Of these, 89 stocks are considered overfished or subject to overfishing. An additional 33 fish and 32 non-fish species are protected by NOAA Fisheries under the Endangered Species Act.

NOAA has the primary responsibility for sustaining these fishery ecosystems and the economies and cultures they support. Significant declines in fishery production over the last several decades have in most cases been linked to excess fishing pressure, often a symptom of inadequate management plans that are based on single stock assessments and rely on limitation of gear or effort to restrict catches. In recent years, the fishery science community has recognized the importance of understanding and managing coastal fisheries at the ecosystem level. This type of Ecosystem Based Management (EBM), increasingly embraced in principle by NOAA, considers multiple components of a fishery ecosystem, including major physical and biological factors that affect recruitment and survival of commercial species and sustainability of their populations. EBM allows development of management principles based on the reality of ecosystem function, and at the same time provides protection for habitats and the biodiversity they support.

Unlike previous management schemes that could be based on landings data and routine surveys, however, EBM rests on understanding a much more complex ecosystem structure, requiring a broader set of observations and more sophisticated interpretation and modeling. Achieving this will require significant participation by the academic research community working with NMFS and other NOAA scientists. Current solicitations for NOAA Cooperative Institutes recognize this need, and timely progress in ensuring the future sustainability of our fishery resources will only be possible through more extramural research support, whether for Cooperative Institutes or by other mechanisms. This is another powerful example of the value of NOAA's research partnership with the larger academic community.

An even broader partnership is seen in NOAA's Integrated Ocean Observing System. IOOS binds together a distributed network of open ocean and coastal observing capabilities with a comprehensive data management and distribution system that will provide immediate, relevant information about ocean conditions to a wide range of users. The system, organized through 11 regional associations that can tailor observational assets and products to local needs, provides the marine equivalent of short- and long-range weather forecasts to fishermen, shipping, recreational boaters, Coast Guard, state and city planners and coastal residents. The development of the IOOS involves NOAA with academic, commercial and government groups to design, build and maintain an observing network that meets real scientific, economic and public safety needs.

All of these examples illustrate the scope of NOAA's responsibilities to the nation, encompassing ocean, land, and atmosphere, and their connections and collective effect on our planetary environment and global society. We in the earth science community greatly value NOAA's important role in all these areas, and the productive research collaborations that we have developed over the years, and which we hope to expand in the future. I want to emphasize that the extramural research conducted by NOAA and its partners is critical to the agency's own success. Research leads to understanding that refines the models that improve prediction that informs policy and therefore helps determine the ultimate economic benefit. In short, it is essential that all of NOAA's operations and services be based on science.

In summary, my recommendation is simple. They echo those of the *Rising Above the Gathering Storm* report. Given the breadth of its mission portfolio, the wide range of science needed to support that mission, and the ever-increasing demand for its products and services, I believe a doubling of NOAA's research budget can only increase the remarkable return on investment cited above. Given those clearly defined economic benefits, we were all pleased to see recognition for NOAA in the American Recovery and Reinvestment Act. Included in that legislation is $111 billion for infrastructure and science—a good investment. But to design and construct billions of dollars of infrastructure informed by 20th century weather forecasts rather than 21st century climate forecasts is short-sighted. We have a National Weather Service; now we need to give the nation the resources to realize its plans for a National Climate Service.

As things stand, the scope of NOAA's mission far exceeds the dollars devoted to it. Many of its facilities and operations are partially paid for out of its research budget, shortchanging the very science and partnerships that support and inform those services and operations and that contribute so greatly to NOAA's national value. In fact, the total research component of NOAA's 2009 budget request, $537 million, is only 14% of its total budget. That mismatch between funding for services and operations and funding for research can only, in turn, shortchange sound policy and decision-support. Increasing NOAA's research budget and recalibrating that balance will be in line with this Administration's determination to restore the voice of science to the collaborative formation of national environmental policy. That will be good for NOAA, good for science, and, most of all, beneficial for the nation.

NOAA AND BASIC SCIENTIFIC DISCOVERIES

Mr. MOLLOHAN. Dr. Avery, NOAA is fundamentally an operational agency, as you pointed out, providing environmental forecasts and maintaining extensive observing systems for weather and climate and to assess marine biota in support of fisheries management.

Ms. AVERY. Yes.

Mr. MOLLOHAN. In what ways does NOAA play a role in basic scientific discoveries and exploration?

Ms. AVERY. Okay. NOAA plays a major role through research that is conducted within their own national laboratories, through the cooperative institutes that are really long-term, sustained relationships between NOAA and academic and research entities and, of course, through individual grants and contracts that go to individual scientists throughout the research enterprise.

This sort of interesting collaboration of research really provides and enables NOAA to access the best expertise for specific needs that then help form and improve the products and operations and services that NOAA provides.

Mr. MOLLOHAN. And how about NOAA's role with regard to scientific education?

Ms. AVERY. Yes. NOAA has taken an increasing role in scientific education. Of course, it is by having these partnerships with the extramural community, you inherently already have a built-in educational component associated with training undergraduate and graduate students.

Additionally, many of those partners and universities and research organizations have outreach programs that are associated with K through 12 efforts. NOAA sponsored something, the Ocean Sciences Bowl, which is always a wonderful tool to get K through 12 communities engaged. And NOAA has engaged itself more broadly with educational opportunities.

So it has that connection through its extramural constituencies and that training is vital for training the future of NOAA's workforce actually.

Mr. MOLLOHAN. What is the scope of those programs?

Ms. AVERY. The scope?

Mr. MOLLOHAN. Yes. Where do they exist; how broadly? How available are those opportunities, and to whom?

Ms. AVERY. The cooperative institutes are spread across the country and I do not know the exact number of them now. I would have to get back to you on that. They span research and education from atmosphere, ocean, and coastal areas, marine areas to fisheries and other important areas.

But the cooperative institutes alone are not the only access to education and training for the future. Also through support of individual principal investigators at other universities who do not have cooperative institutes, you get a vital connection with educational enterprise.

Mr. MOLLOHAN. You referenced Regional Integrated Science and Assessment programs in your testimony, which reach out to stakeholders to incorporate more science into resources management in order to improve how communities, planners, managers, and end users, such as farmers and public utilities prepare for and adapt to changing climate.

Ms. AVERY. Yes.

Mr. MOLLOHAN. Where are those partnerships?

Ms. AVERY. The partnerships at the University of Colorado, University of—these are the headquarters. They actually develop a lot of partners. But University of Colorado, University of Arizona, University of Washington, University of California, out in Hawaii, University of Florida or Florida State. I am showing an embarrassing glitch there that I do not recognize.

Mr. MOLLOHAN. No. No, no, no, no, no, not at all.

Ms. AVERY. But basically it is actually a fairly small program, but a very innovative program that NOAA put together in developing experimental sort of pilot projects that more actively, if you will, structure engagement of scientists with stakeholders in a very problem focused area that allows stakeholders who have decisions to make that are important, have important stressors associated with climate and climate variability or climate change to really help develop the right science, the right information, the right decision tools that can help, for example, manage the west water resources or manage an ecosystem in the marine environment.

Mr. MOLLOHAN. What is interesting about that program is that it is an inland focused program, is it not?

Ms. AVERY. Yes.

Mr. MOLLOHAN. I mean, it looks like it is focused on a western water problem.

Ms. AVERY. Yes.

Mr. MOLLOHAN. How did NOAA get to that issue in the middle of the country?

Ms. AVERY. I think that is a good question.

Mr. MOLLOHAN. I know, which I applaud you for. I just want to understand how you got to that.

Ms. AVERY. Yes. It got to that, it emerged out of the climate program within NOAA, okay, and looking at the intersection of where climate information could have a tremendous impact on the economy.

And if you look at western water, it is one of the key economic drivers. It is the natural resource that is a key economic driver for the west.

Mr. MOLLOHAN. Yes.

Ms. AVERY. And so there is sort of a natural fit between the universities and their scientific expertise and their public outreach missions with NOAA's climate and then——

Mr. MOLLOHAN. Expertise.

Ms. AVERY. The expertise. And it occurred at the same time that NOAA's ENSO predictive capability was beginning to mature to a sufficient stage that there was some skill, if you will, in predictive ENSO capability.

In fact, a lot of the initial resources were dedicated to really looking at climate variability on ENSO scales rather than global climate change.

Mr. MOLLOHAN. Yes.

Ms. AVERY. That is evolving, of course, as the science evolves as well. But you are right. I have often questioned it myself and I would think that there would be a need for additional RISA efforts that might encompass coastal city environments, marine environments.

Mr. MOLLOHAN. Well, for those of us who are in-landers, it is actually encouraging because we think that we have these kinds of climate issues, these kinds of water issues, and we are the headwaters of everything that gets to your coastal jurisdictions.

Ms. AVERY. That is right.

Mr. MOLLOHAN. So I actually applaud that. But this program looks like it is facilitating the competing interests of stakeholders and trying to accommodate them in some way.

Does it get down to that level of detail or are you simply providing data?

Ms. AVERY. No, no, no. That is what is really unique. By the way, prior to Woods Hole, I was at the University of Colorado, so I was an in-lander too.

Mr. MOLLOHAN. Oh, well, now we start understanding.

Ms. AVERY. And, actually, I have helped with the development of the RISA.

Mr. MOLLOHAN. I bet you did.

Ms. AVERY. And the interesting thing that I found about the whole development of this program was it restructured the way researchers think and scientists think. And it is not just that I am going to develop information and give it to you. It really is sitting down and developing sustainable stakeholder communities and sustainable user interactions understanding how decisions are made.

One of the first things that the RISA Program in Colorado did was actually sit down with water managers and look at a water decision calendar. What time do you make decisions about managing water? What kinds of scientific information would be needed at what point in the year?

Mr. MOLLOHAN. Yes.

Ms. AVERY. And then from that, that helped kind of inform what kind of science really needed to be done. So taking something as simple as looking at water—scientists often look at water and display data about water on a calendar year instead of on a water year.

Mr. MOLLOHAN. Yes.

Ms. AVERY. And the water year in the west begins in the fall and goes through the summer. So something like that.

But then also, it also helped inform what kind of process questions that we really do not know in order to address some of those scientific products that the stakeholders could use within their decision calendar.

Mr. MOLLOHAN. Yes.

Ms. AVERY. That is a typical example, but it has been very active and they have grown tremendously with little money actually, very little money.

Mr. MOLLOHAN. Well, great. All the better. Thank you, Doctor.

Ms. AVERY. Thank you.

Mr. MOLLOHAN. Mr. Culberson.

Mr. CULBERSON. Thank you, Mr. Chairman.

We are delighted that you are here today. This Committee is unified in our passion for investing in the sciences and, as I said, really do appreciate your independent objective opinions here today, Dr. Avery and Dr. Serum.

I represent west Houston. I am here today on behalf of Mr. Wolf who has a conflict and cannot join us, Mr. Chairman, so I thank you for the time.

I want to touch on a couple of areas. I cannot begin, however, without—I want to pass this on to you, Mr. Chairman. This is a quantum wire from Reich University and I have already given one, I think, to Adam. I need to give one to each member of the Committee.

A particular passion of mine is nanotechnology which NIST has been especially key in. That is a single wall carbon nano tube, Mr. Chairman, that they are working, they are weaving them together into a wire. And a carbon nano tube is essentially a hollow structure of carbon 60 molecules that electricity is transmitted ballistically without any resistance down the wire.

And once they weave that into a wire, and NIST has been a key part of this, they will be able to transmit theoretically a hundred million but they prefer I say a million times the electricity carried in those gigantic steel power lines that we see today running along freeways in a wire about the width of your little finger from New York to Los Angeles with zero loss of electrons because there is no heat resistance. There is no loss to electromagnetic radiation. And this revolutionizes, Mr. Chairman and Committee members, not only the transmission of electricity but the storage of electricity.

And using a distributed system that the scientists at Reich University developed, a device the size of a washing machine, essentially a household appliance, using carbon nano tube technology could store enough electricity—you could buy it off the grid at night, store it in your electrical storage device in your laundry room, and then run your entire house and charge up your electric car and have enough electricity left over to sell back to the grid.

In a distributed network like that, you could make the United States completely free of foreign oil, tell Saudi Arabia to jump off a cliff, the Middle East, or any of them. And it would be a magnificent achievement. And NIST has been a key part of this, Mr. Chairman.

And the standards that you establish, I think that the Alliance for Nano Health, you have been working with some of our scientists at Reich University.

Mr. SERUM. Yes, we have. Yes.

Mr. CULBERSON. And Dr. Mauro Ferrari. They are not only helping us make us energy independent but also identifying cancer when it first appears, a few cells, and be able to zap the cancer cells with gold nano shells literally killing every cancer cell in your body no matter where it is hiding without drugs, without surgery, without side effect, without chemotherapy, taking out every cancer cell in your body, instantaneously cauterizing them.

Essentially it is the difference between a carpet bombing with a B52, which is what we are doing today with chemotherapy, and precision surgical strikes taking out Saddam Hussein without even singing the eyebrows of the general next to him.

And this is all possible because——

Mr. HONDA. We have seen.

Mr. CULBERSON. Right. It is coming, though, Mike. And you guys are doing some of that on the West Coast as well at Stanford and up in Palo Alto. I do not mean to neglect New York and the work that is being done on the East Coast.

Mr. Serrano, you may be doing some of this as well, but it is——

Mr. HONDA. He is from Wisconsin.

CLIMATE CHANGE SCIENCE

Mr. CULBERSON. Well, it is an important chance to brag on NIST not only for the work you do on nanotechnology and also on NOAA. And I appreciate very much the work that you do at Woods Hole.

And let me ask a couple of, if I could, quick questions because we are voting and we will be rotating in and out during this vote.

The work that NOAA does, and you have in particular, Dr. Avery, worked both with NOAA and the Climate Change Science Program, it would be very helpful from your perspective on the outside from Woods Hole, if you could give the Committee your assessment how the federal government's Climate Science Program needs to change to deal with the challenges we are going to see in the future. What should the Committee be thinking about doing to enhance, change our Climate Science Program?

Ms. AVERY. Okay. I think that the Climate Change Science Program, which has done wonderful things over the last couple decades, is evolving to not only looking at the impacts associated with policy that would lead to mitigation efforts, primarily associated with our use of energy, but I think it needs to probably expand its focus a little bit more, do more work in the adaptation area as well.

I think you probably are poised for the modeling to get down to a regional scale with more skill. And I think most importantly is the real need to get an observing system.

Mr. CULBERSON. Well, you say we only have 70 buoys in the ocean.

Ms. AVERY. That is right.

Mr. CULBERSON. And so we need to expand the number of buoys. And when you say get down to regional modeling, that is modeling both the atmosphere and the ocean. So clearly we need more ocean buoys. We need to expand that program.

Ms. AVERY. Yeah. If you think about it, I like to think about it this way, I think sometimes people think of climate as only an atmosphere problem. Climate is really, the climate system is atmosphere, ocean, and land.

Mr. CULBERSON. Yes.

Ms. AVERY. Okay. And the climate is going to respond. It does not say, oh, this is an atmosphere part of the problem or this is the ocean part of the problem, this is the land part of the problem. It is an integrated response.

Mr. CULBERSON. But the oceans are the primary carbon sink——

Ms. AVERY. Yes.

Mr. CULBERSON [continuing]. On the planet. That was, in fact, one of the questions when I get back to my second round, Mr. Chairman, I want to ask you about to be thinking about, to talk to us about the work that you have done in researching fertilizing the ocean with powdered, I would suggest, nano particles of iron oxide in order to—because the oceans are, Mr. Chairman, soaking out—this is an article from February 9th, 2007 of the Journal of Science—the uptake, natural uptake of carbon dioxide by the ocean combined with the dissolution of marine carbonate will absorb 90 percent of the carbon dioxide released by human activities. So it really is—this is 90 percent. The carbon sinks on earth are going to come from the ocean, right?

Ms. AVERY. It is really impressive. If you look at a map of where the carbon uptake of the oceans is occurring, the largest peaks are in the north Atlantic and in the southern oceans.

Mr. CULBERSON. And then they also discover the Bay of Bengal too——

Ms. AVERY. That is right.

Mr. CULBERSON [continuing]. The Ganges Rivers.

Ms. AVERY. Yeah. And, you know, the oceans, in many ways, you can almost say perhaps they are the first victims of climate change because of acidification issues, the dead zones that we are seeing in the oceans.

Mr. CULBERSON. Unless you use iron oxide, powdered.

Ms. AVERY. We will talk about iron oxide.

Mr. CULBERSON. Acidify the ocean.

Ms. AVERY. Yes.

Mr. CULBERSON. Right?

Ms. AVERY. We need to actually do some further studies to see if——

Mr. CULBERSON. We will talk about this on my second round, Mr. Chairman, but it is something I do want you to be thinking about. But the Committee does need guidance. We are voting and I will pass the witness. But we do need guidance, if we could, about what we need to do to change the Climate Science Program to make it allow us to do better modeling.

Thank you.

Ms. AVERY. Wonderful.

Mr. MOLLOHAN. Thank you, Mr. Culberson.

Mr. Schiff.

NOAA PARTNERSHIP WITH FEDERAL AGENCIES

Mr. SCHIFF. Thank you, Mr. Chairman.

Dr. Avery, as you know, NOAA undertakes a wide variety of research related to climate, but NOAA does not always have the inhouse expertise or the technological capability. In particular, satellites provide some of the most useful global data for climate change research and are key to NOAA's missions.

Do you think NOAA has taken the right steps to partner with NASA and other federal science agencies on climate change, in particular when it comes to gathering weather and climate related satellite data? What do you think the appropriate roles are for NOAA operated satellites versus NASA operated satellites versus the purchase of data from private satellite operators?

Ms. AVERY. Good question. And certainly there have been many Academy studies that look at the NASA/NOAA relationship.

NASA has primarily been the source of research missions that help us in a way define research tools, to look at understanding of the planet Earth. But in that context, they often have a very important link to, a potential link to an operational entity.

So you see any numbers of observations that were from satellites initially developed within the NASA framework and then have been proved being of great operational importance, whether it is an infusion into a data simulation that initializes a model, such as a weather model, or whatever.

That transition from a research sort of satellite to an operational satellite is a difficult transition. And there have been a number of studies that have suggested ways to make that transition a little bit smoother, ways to make sure that the data gets there or gets into an operational framework.

The problem is a lot of times, there is not necessarily the expertise to hand it off or necessarily the resources to hand a research satellite over into an operational entity. And that has been basically some of the problems.

And I worked on the Decadal Study, the NASA Decadal Study for Earth satellite observations. And at that time, one of the critical things that we were looking at is the future of NPOES and where was NPOES going. And a number of key what we would call climate variables or climate observations were getting thrown off NPOES because of budgetary constraints. And I do not know what the status of that is right now, but it is a difficult thing.

You do not want to just look at satellites though. In situ observations are important, too, and particularly for observing the ocean in the climate system. Remember the ocean—satellites you can only get near the surface of the ocean. You can only measure the surface of the ocean. You cannot penetrate the depths of the ocean because electromagnetic wave radiation will not penetrate and that is the primary sensing mechanism.

So it is a difficult problem. I think it is an important problem. I think it is very important that NASA and NOAA partner together.

On the private side, the question really becomes, and I have asked this question myself, should NOAA put out a request for data or should NOAA actually operate its own infrastructure and what can the private sector provide?

And the real question, the stumbling block is when you are looking at weather, when you are looking at climate, when you are looking at ecosystem management, it is the continuity of the data and whether the private sector can provide that continuity in economic times where the industry may come and go would be the question that one would have to ask.

Mr. SCHIFF. One other micro question. The unsuccessful launch of the orbiting carbon observatory.

Ms. AVERY. Yes.

Mr. SCHIFF. What is your thought? Is that a must replace situation?

Ms. AVERY. Well, it certainly was in many scientists' minds and my own sort of the key component of taking that next step and understanding our carbon balance in the climate system and on the planet.

That combined with a lot of programs that were being discussed in terms of complementing that satellite program with in situ observations was really key. So the loss of that satellite was devastating and it would be, I think, highly desirable to see if it could be replaced.

Mr. SCHIFF. Thank you, Mr. Chairman.

SATELLITE PROGRAM

Mr. MOLLOHAN. Well, just following up, what would be a substitute for the satellite?

Ms. AVERY. To get the global coverage, you would need the satellite program. The satellite program was a stand-alone program. It was granted then, but it would get the surface sort of carbon budget and then there is talk about looking at the ocean imbedded carbon that is deeper down in the ocean that you would not get from a satellite observatory.

Mr. MOLLOHAN. You may have answered Mr. Schiff's question just exactly the way he wanted the answer. But, do you recommend it be replaced or do you think it is essential that it happen?

Ms. AVERY. Yes.

Mr. SERUM. Yes.

Ms. AVERY. Yes.

Mr. MOLLOHAN. Mr. Serrano.

Mr. SERRANO. Thank you, Mr. Chairman.

Dr. Avery, I know that as a Director of the Woods Hole Institution, you have had a long relationship with NOAA that has included important NOAA funded research.

Ms. AVERY. Yes.

Mr. SERRANO. NOAA through its Educational Partnership Program and its cooperative science centers at minority serving institutions has been at the forefront of training and encouraging our next generation of minority students.

Ms. AVERY. Yes.

Mr. SERRANO. But I also know that you have a fellowship program at your institution. Could you share with the Committee how that program works and what lessons we have learned that could be used by NOAA in general as we move forward?

Ms. AVERY. Okay. Yes. We have been very, very fortunate to have a very active fellowship program for students beginning at the undergraduate level. We have a summer sort of scholarship internship program that brings students to Woods Hole, undergraduate students to Woods Hole for a summer experience.

They have a month of intensive classes and then two months of the opportunity to do research. Some are able to actually go to sea. And it swells Woods Hole, let us say, in the summertime. It complements the tourists there as well.

That program has been really essential in many ways of exciting undergraduate students about the possibilities of doing graduate work in ocean sciences or in geosciences more broadly. Often undergraduates do not necessarily get an exposure in their undergraduate curriculum to atmospheric science, ocean science because they are more traditionally the physics, chemistry, and biology efforts in the universities.

And a lot of students who go through that summer program actually become excited and actually go on to graduate school in ocean sciences around the country.

Woods Hole happens to also have its own graduate degree program as well.

We are really also seeking opportunities to work more closely with minority serving institutions, particularly during the academic year on a longer time scale that allows us to develop partnerships with faculty at minority serving institutions and our scientists here. And that is a program that is in the development stage and we have got some initial seed funding for that and some partnerships that we are going to be working on.

Mr. SERRANO. Well, how do these students come to you?

Ms. AVERY. They apply. We have a very well advertised program on the web. We certainly get the information out there as much as possible through our network of university colleagues. And then they basically apply.

Mr. SERRANO. Well, I encourage the work you are doing and I support it. I encourage it.

I think that too often in our society, we tend to tell some students to go in certain directions, most students in certain directions, but we do not encourage students who ordinarily would not know about certain professions or certain work, of the role they can play.

And I think more and more of working with minority serving institutions to say, you know, aside from everything else that is available in study, here is something different and exciting and how you can play a role within the society.

And I think that we always talk about diversity in this society, but it is also diversity of what you want people to be involved in——

Ms. AVERY. That is right.

Mr. SERRANO [continuing]. You know, to move it around, not just to keep certain people in certain places. So I encourage and I support your work.

Ms. AVERY. Thank you very much.

Mr. MOLLOHAN. Do you want to go now?

Mr. HONDA. Yes. I have real quick questions.

Mr. MOLLOHAN. Okay. Mr. Honda.

Mr. HONDA. Thank you, Mr. Chairman.

A couple of quick questions. And if we do not have time for a response, maybe get a written response. But to follow-up on the orbital carbon observatory, launching of the satellite was based upon the failure of the rocket. But the cost of a satellite is probably tremendous.

Were there multiple functions on that satellite that could have been distributed to other satellites so when expiration of satellites occurred that you do not have all the functions expire at once and it just does not seem like a smart thing to do?

Ms. AVERY. Yes. That is a good question. And, unfortunately, I do not know enough details about the specific payload and the sensors and whether they could be split up or launched on other platforms. So I could take a note and get back to you on that.

Mr. HONDA. I would appreciate that.

The other quick question is, there was a collaboration agreement between NOAA and NASA on calibration and other things. One agency was not able to do it because they had no money.

Is that plan coming together again for this go around and, if so, are there sufficient funds? If not, why not?

Ms. AVERY. I will have to again find out more information about that for you.

Mr. HONDA. And one other area that NOAA works with is San Jose State University. They have got some projects with the Navy postgraduate school.

Ms. AVERY. Yes.

Mr. HONDA. My question related to that is, taking that kind of collaboration and working together and the information that comes out of it and looking at demonstration programs, is there any thought of extracting instructional materials for pre-school to post-graduate in helping us teach information in a consistent, ongoing way so that by the time a youngster is out of school, either six, eight, high school or graduate school, that they are a critical consumer and a user of energy so that we grow not only individuals but a community or a nation of folks that will be sensitive to the carbon footprint and then start demanding these kinds of activities from people like ourselves?

Ms. AVERY. Yes. Certainly the potential is there. There is a wealth of information, consistent information and scientific information that can be used in that educational pipeline and in that public mission of educating people to become informed citizens on these difficult problems.

Mr. HONDA. Those are obvious kinds of things, but is there anything that is being thought of in order to execute and make it happen because we are talking about innovation, we are talking about, you know, continuous growth?

Ms. AVERY. Yes.

Mr. HONDA. If we look at Moore's law, we want to make sure that Moore's law continues.

Ms. AVERY. Yes. I do not know if there is one sort of integrating strategic plan that is pulling it all together. There are pockets, if you will.

So you could say, for example, the Regional Integrated Science Assessment, the information that is coming out of that activity basically is coming out in user friendly information reports that are transmitted widely, that are on the web, that can be part of the education opportunity. And it is one of their goals.

Mr. HONDA. And perhaps you have someone in these inter-agencies that you could ask and say would you guys conjugate about it and get back to us on a conceptual framework or a possible scenario that we can look at to put forward so that we can fund it and make it happen.

Ms. AVERY. Right.

Mr. HONDA. It would be a crime to let this information and opportunity pass buy.

Ms. AVERY. Yes. And I know that NOAA has a major education effort going on. I just do not know if they are doing something at that level or not.

Mr. HONDA. All right. Thank you.

Mr. CULBERSON. Thank you, Mike.

If I could, I would like to ask each one of you to give us your opinion on what, from your perspective, would be the best use—for example, Dr. Avery, NOAA received about $600 million in the stimulus bill for construction, reading from the report, general guidance said for construction, repair of NOAA facilities, ships, and equipment, that could certainly include buoys, facilities, ships, and equipment, comma, for the purpose of to improve weather forecasting and support satellite development, period.

And out of that 600 million, 170 million shall address critical gaps and climate modeling and establish climate data records for continuing research into the cause, effects, and ways to mitigate climate change.

Ms. AVERY. Yes.

STIMULUS MONEY

Mr. CULBERSON. Could you share with us, Dr. Avery, first.

And then, Dr. Serum, for NIST, could you tell the Chairman and the Committee what in your opinion would be the best use of that money, for example, that NOAA received, the $600 million in the stimulus.

Ms. AVERY. Okay. So there is already, I think, $170 million targeted, as you said, for the modeling capability. And NOAA has been——

Mr. CULBERSON. That is broad.

Ms. AVERY. It is gone.

Mr. CULBERSON. I am sorry?

Ms. AVERY. The 170 million?

Mr. CULBERSON. Yes, ma'am.

Ms. AVERY. Was for the computing.

Mr. CULBERSON. For critical gaps. It is just the only guidance that Congress has given is to say shall address critical gaps in climate modeling and establish climate data records—

Ms. AVERY. Yeah.

Mr. CULBERSON [continuing]. For continuing research. So within that, that reasonably gives NOAA some discretion.

Ms. AVERY. Yeah.

Mr. CULBERSON. How should they use that?

Ms. AVERY. I think one of the things that they have been sorely needing is a computing capability, enhanced computing capability for their models. As the modeling effort goes to higher and higher resolution to try to incorporate more systems approach as well as a resolution that gets to the regional scale, you are going to need more computer power.

And NOAA has been hurting, if you will, for that computational power. So investment in that computational power would be——

SUPER COMPUTING

Mr. CULBERSON. Now, rather than NOAA buying one of those computers, because I have seen the IBM blue jean computer up in the Watson Labs—my brother builds IBM super computers to model seismic data for the oil and gas industry in Houston.

And they are extraordinary, Mr. Chairman. They can actually with these massive computers that run so fast create three-dimensional color images that you can wear three-dimensional goggles and get inside the geologic formation and see it, similar to what you are talking about.

Because those things change so fast, they have to buy new ones about every three, four, six months to keep up. Would it be better for NOAA to contract that work out because that is what essentially the big oil companies are doing? They hire companies like this one my brother—my brother works for IBM. He subcontracts to a company called Western Geophysical and then Western Geo, you know, Exxon will hire them, Shell, Contico will hire Western Geo or some other company with giant super computers who can give Contico the best value for our dollar.

Shouldn't NOAA approach it the same way and simply contract out that work for giant super computer modeling?

Ms. AVERY. I think it depends——

Mr. CULBERSON. It would be cheaper and more effective and efficient; would it not?

Ms. AVERY. Yes. I think it depends on what the end product might be, because a lot of the super computer, the modeling work that is being done is still a tool for the research effort itself. So you need that close connection between the researcher and the computational code, if you will, the models that are being generated. It is not like there is a set model there that you could just hand off to someone to run, to do several runs.

So I think it depends. I think I would need to know more and to weigh whether a contracting arrangement would be better than actually purchasing.

Mr. CULBERSON. Atmospheric modeling data you are saying is different from seismic data and you could not just hand that data over as the oil industry does to a company like Western Geo? They just give them a big slug of seismic data and they crunch it over a couple of days and then give them the visualization. That is what you are talking about.

Ms. AVERY. Oh, okay. You are talking about the data aspect of it?

Mr. CULBERSON. Couldn't the modeling data simply be, the atmospheric data be handed over to a private company like that that does really top-notch work with cutting edge computers and do it at a far better, cheaper price for the taxpayers and better computational power at a better price?

Ms. AVERY. I do not know. You would have to do an analysis, I guess, and determine which way would be the best.

Most of the time that I look at, as I see scientists working with modeling and data in the super computer, a lot of that work is basically still in the research phase and they are still developing the models or they are still developing the data sets.

If the data sets were already there or the models were already done and were all agreed upon and there was no further research, in other words they were set, you could then probably hand it off. In your case, the oil companies, did the oil companies have the models themselves——

Mr. CULBERSON. It is raw data.

Ms. AVERY. It is just raw data?

Mr. CULBERSON. I mean, it is what you are talking about.

Literally it is raw data, Mr. Chairman, that the oil companies, and literally it is a competition. That is what my brother does for IBM. Western Geo has HP and IBM building these things.

Is it the second vote?

Mr. MOLLOHAN. Yes.

Mr. CULBERSON. Okay.

Ms. AVERY. Yes.

Mr. CULBERSON. I am going to run down and vote. He is very generous with his time allowing me.

Ms. AVERY. He is. I see.

Mr. CULBERSON. But we would love to hear from you. I know he would too. And I will quit interrupting with questions. How should NOAA spend the money and how should NIST spend that money?

Ms. AVERY. Okay.

Mr. CULBERSON. And I will go vote. Thank you for your generosity with the time.

U.S. COMPETITIVENESS

Mr. MOLLOHAN. Dr. Serum, this mission is to promote U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology in ways that enhance economic security and improve our quality of life.

Which segments of our economy depend on NIST research products and services?

Mr. SERUM. It turns out that almost every industrial segment that one can think of that NIST affects in one way or another, one can consider from the standards that are defined for mixing cement for durability, hardness, longevity and so forth, all the way up to healthcare and doing research in the latest biotechnology, DNA array technology.

And the fundamental aspect of NIST, of course, is making accurate measurements so that industries can use standards that can be measured. And so it really is just about every industry that I can think of NIST touches in some fashion.

Mr. MOLLOHAN. And give us your thinking about how NIST impacts the lives of ordinary citizens. Give us a relevant statement of NIST for the ordinary population.

Mr. SERUM. Well, you mentioned in the mission that their focus is on improving the quality of life. And so perhaps one might begin with the field of healthcare.

One can cite many examples, but all the way back in the, I think it was something like 1917, NIST, there was a lot of problems with dental amalgams and NIST got involved in healthcare way back then to define a standard for mercury amalgams in dental fillings.

As one moves along, one can talk about standards for glucose measurements, the little meters that measure a diabetic. There are standards for defining that. The cholesterol test, there is a standard. And NIST has worked those out.

And certainly in healthcare, last but not least, all of the diagnostics that back in the early 1990s when the world transformed to DNA measurements as a diagnostic, it turns out that, and I was part of that at Hewlett Packard, that the arrays were not very accurate and depending on whose one used, you could get different results, different interpretations. And NIST had undertaken an effort to work out accurate measurements of DNA and working towards standardization of those devices.

I can mention things like fire safety. NIST defines the fire retardant requirements for——

Mr. MOLLOHAN. Let me interrupt——

Mr. SERUM. Yes.

Mr. MOLLOHAN [continuing]. You for just a moment. We have two more votes. These are five minute votes. This vote has 33 more seconds. We will vote this vote, vote the next vote, and we will resume. And the hearing will be in recess until we do that.

[Recess.]

NIST SETTING STANDARDS

Mr. MOLLOHAN. The hearing will come to order.

Following up, Dr. Serum, on those questions. So one of the big benefits, of course, NIST sets standards. And those standards are followed. Certainly the United States has standards for everything, I guess, almost.

Mr. SERUM. Yes.

Mr. MOLLOHAN. What has been the experience with standards setting around the world and to what extent has NIST provided leadership in that area?

Mr. SERUM. Actually, NIST is a very, very highly respected agency throughout the world. The French organization, I think it is called System Internationale, SI, holds the world's standards on things like the meter and the kilogram and things like that.

And I had the opportunity to participate in an international conference that was related to what are the most critical measurement needs as we look forward in the 21st century related to bioscience measurements and healthcare. And it was an international meeting and it was important enough to other international agencies that they sent their directors, the heads of the agencies from around the world, the Netherlands, over in the Middle East, and France and Germany and so forth.

And a number of them knowing that I was the Chairman of the Visiting Committee came up to me and told me what phenomenal respect they had for NIST as a standards setting body.

In addition, it is probably worthy of comment that NIST acts as sort of a mentor to developing standards organizations in South America and places where they do not have a lot of experience and they look to NIST as both a model and a mentor. NIST has hosted people for that.

And, of course, we are a global economy and global standards are absolutely necessary and for people to adopt standards globally that NIST promotes and develops is extremely important for U.S. industry.

Mr. MOLLOHAN. So in addition to being a model and a mentor, NIST is a guide?

Mr. SERUM. Absolutely, yes.

Mr. MOLLOHAN. And the standards are followed?

Mr. SERUM. Yes. The process of standardization is not an easy one. I was involved in a variety of standards activities in software and hardware while I was in Hewlett Packard. And it is a little like pushing on a rope. You do not know where it is going exactly and you have to have quite a bit of patience.

But, yet, a lot of leadership demonstrating why the standard is necessary and then convincing organizations to do it because there is nobody holding the whip that says they have to do it, each country is sovereign, and so it is only by respect and by the quality of the standard and the details that NIST standards are adopted and respected.

Mr. MOLLOHAN. Well, just as a general proposition, what is the trend line? I guess what I am trying to get at is the relationship between standards setting for products and processes and the acceptance of those standards and processes by other economies, by other governments, and the importance of that acceptance to our economy.

If I am understanding your statement, in the past, the United States has typically been followed in many areas. Please mention some cases where it was not, and is this true looking forward or are there any concerns that U.S. leadership in standards will not be followed? Are we ceding leadership in this area and is there any aspect of standards setting with which we should be concerned and looking at?

Mr. SERUM. Well, based on my interaction with NIST, I guess I could answer that maybe in two different ways. One, there are standards that involve international trade that may be somewhat mundane, may have very strong opinions by other countries, Germany, France, Netherlands, and so forth, in which the United States has good respect and plenty of leadership, but not a dominant role.

The other point that I would make is NIST is fundamentally a research organization and it goes about developing standards from the foundation of very accurate measurement that can be developed upon which a standard is based.

And as I look across NIST and to answer your question about what does the future look like, I would say I would expect NIST to take an even greater role internationally because of the role of technology and the rapid changes that are occurring.

Mr. Culberson talked about nano particles now or tubes, nano materials. I recently saw an expert opinion that as much as 50 percent of all future technology-based products will involve nano materials.

And that is one of the reasons why the great amount of work on toxicity of nano materials because should the horse get out of the barn and then one finds toxicological effects after the fact, it could be devastating to the economy. And so NIST has taken a very major role in the toxicology of nano particles.

Mr. MOLLOHAN. And how does that relate to standards setting?

Mr. SERUM. Well, again, that is basic research. But when one thinks of nano particles, the way one's body ingests material, nano particles will be in everything you can think of.

Mr. MOLLOHAN. Exposure standards?

Mr. SERUM. Exposure. So the dimensioning, the size, the geometry, the chemical properties of a nano particle right now cannot be predicted a priori. The science just is not known. So doing fundamental science in that work, trying to relate structure and composition of nano particles to toxicity is really important.

Mr. MOLLOHAN. Thank you.

The 2010 suggested budget request is .8 billion. And that is notionally broken down for NIST. And there are additional resources provided in "The Recovery Act" which we would add to the 2009 funding.

Looking forward, Dr. Marburger, the President's science advisor last year, testified before this Committee in response to some question to the effect that if you had additional dollars, where would you spend them in science, and he said NIST.

Mr. SERUM. Good for him.

Mr. MOLLOHAN. And so he was asked what kind of numbers are you talking about. And I am not going to say exactly because I would be guessing, but it was a really surprising multiple of the NIST funding. Say it was twice or three times. And, actually, I think it was some multiple higher than that.

But whatever the multiple, do you agree with that and why?

Mr. SERUM. Yes, I——

Mr. MOLLOHAN. Now, this is vis-a-vis other science accounts.

THE AMERICA COMPETES ACT

Mr. SERUM. Yes. I understand. Yes, I do agree with it. In fact, I have said privately to people that when one talks about "The America Competes Act" and talk about doubling the budget, that represents about a seven percent per year growth. And I have said in response to that we are very grateful for that because of the challenges.

Mr. MOLLOHAN. That is the right thing to say first.

Mr. SERUM. Yes. But I could easily see the NIST budget doubling and enabling them to make very good use of those funds.

When one looks at the challenges that NIST is involved in related to fuel cell research and energy, the energy grid, and that is an easy word to say and it is an extremely complex problem to solve, you do not——

Mr. MOLLOHAN. The energy grid?

Mr. SERUM. The energy grid.

Mr. MOLLOHAN. Yes.

Mr. SERUM. You do not just plug all the grids together and you have an energy grid. You have to have a whole new infrastructure of security management. You need to have standardized equipment that knows how to measure energy as it is moved around.

And then in the context of alternative energy sources, one faces a whole new set of measurements to assure that as energy moves around on a new grid that it does so and is managed in a secure fashion, in an accurate fashion.

When one looks at healthcare, the way NIST has managed their research, which I enthusiastically support, is they have these main thrusts of we have a deliverable to make and we have to make progress. And they are full of ideas, full of new technological ideas that are just waiting to be nurtured.

And what they do is they have a competitive sort of evaluation each year in which they nurture some of the more promising ideas just enough to keep the germ alive but not enough critical mass to actually fund them.

There are many, many of those that have been worked on and are waiting to blossom. There are very, very outstanding ideas for transfer of technology to industry related to energy and infrastructure and information technology. A complex system you are talking about, NOAA, and the management of that data.

When one looks at climate change, one of the big problems is knowing that there are so many variables that actually exist. NIST has a lot of competency in complex systems information science.

And so I could go on and on about germinating ideas that could utilize that money almost instantaneously.

Mr. MOLLOHAN. Well, I may let you do that because I am very interested.

Mr. Bonner has not had a chance to ask questions.

Mr. Bonner.

Mr. BONNER. Thank you, Mr. Chairman. And I am sorry that I was not here at the beginning for the opening testimony.

Mr. MOLLOHAN. You made a point of being here early before.

GULF COAST AND NOAA

Mr. BONNER. I had some constituents that I needed to see. But you may have covered this, Dr. Avery. I know it is in part of your written statement. But first of all, a compliment. I think I am the only member of the Subcommittee that actually lives on the Gulf of Mexico. And we have had, as you know, quite frequent occasion to use the talents and the services of NOAA, the National Weather Service, and others who have come to our rescue before the storms have come and certainly afterward. Ivan, Katrina, Rita, a lot of damage, in fact, with Katrina obviously the worst natural disaster in U.S. history. So thank you for the wonderful work that is done there. Red tide, living on the water and actually seeing how something that has an innocent enough name can do so much damage and destruction is something that, again, I give hats off to NOAA.

On the National Marine Fisheries Service, however, I will have to ask you, and I am doing it in a respectful way. Based on your experience, is there room for new thinking within the processes by which MNFS considers all the data with regard to putting fish population on a list? An example. The Gulf Coast charter industry is a $650 million a year industry in my district. These are small, family businesses. Mom and Pop take out a loan to get a million and a half, $2 million boat. And when they are told, when scientists in our own academic universities with marine biology degrees are saying that the red snapper population is ample, or has enlarged in the last ten years. And then they are told by National Marine Fisheries people that no, it has not. It is over fished and it is endangered. You cannot expect a family to go down and charter a boat for $5,000 to go out and catch two snapper. And so my question to you is, based on your experience, does the mind set at MNFS allow for new ideas and new information that could help perhaps bring a more balanced perspective on something such as listing a fish?

Ms. AVERY. That is a good question. I think that you will see right now a growing awareness that sometimes managing fisheries in terms of a single stock works, more often it does not. And it is because you are looking at the, you really need to look at the entire ecosystem that supports that particular species. And that is what we mean by ecosystem based management. And that approach to fisheries I think is one that should increasingly become something that NOAA looks at. I think there is even an interesting twist on it, now, in that whereas before without the climate problem one might have looked at that ecosystem from a stationary climate perspective, nowadays you have the additional stress that that ecosystem could be stressed by climate change. NOAA is the right agency to kind of merge that marine effort, fishery effort, the ecosystem based management effort with the climate effort to come up with something that has new ideas on how to actually get good, sound, consistent information out. But it is a wonderful topic that NOAA is positioned to do. Or should be positioned to do.

Mr. BONNER. Well, we look forward to working with NOAA.

Ms. AVERY. That is good.

Mr. BONNER. In that conversation.

Ms. AVERY. That is great.

Mr. BONNER. That is all I have, Mr. Chairman.

Mr. MOLLOHAN. Thank you, Mr. Bonner. Mr. Culberson.

Mr. CULBERSON. Thank you, Mr. Chairman. Mr. Chairman, would it be possible for me to have, maybe, two, may I ask two sets of questions? Do I have time for, one on, I wanted to ask them about how did——

Mr. MOLLOHAN. For a reasonable length of time, you can ask——

Mr. CULBERSON. Yes, sir. I wanted to make sure I did not run out. I want to ask you about——

Mr. MOLLOHAN. But you may run out——

Mr. CULBERSON. I will be prudent.

Mr. MOLLOHAN. All right.

FERTILIZING THE OCEAN

Mr. CULBERSON. I will be prudent. Thank you, sir. If I could ask you very briefly and succinctly, because I want to get to a second set of questions with you, Dr. Avery in particular, about fertilizing the oceans. Could you tell us in your own opinion how, what would be your best recommendation, again short and succinct, on how NIST and NOAA should spend the additional stimulus money?

Mr. SERUM. Yes. I think that one of the things that happened this year in the NIST planning activity was a matrix between the feedback that they had gotten in all of their programs related to priorities and comparing it to the new administration's priorities. And there was actually an excellent amount of overlap related to moving ahead in energy field, in healthcare, in infrastructure. And so I believe that, well, I would say the visiting committee supported those initiatives and many are just starting as initiatives.

Mr. CULBERSON. You know, NIST has very broad discretion——

Mr. SERUM. Yes.

Mr. CULBERSON [continuing]. In how that money is used.

Mr. SERUM. Yes. So the way I would answer it is, we believe that those are excellent priorities related to accurate measurements in climate change, moving ahead in understanding fuel cell function more effectively, photovoltaics.

Mr. CULBERSON. Especially with carbon nanotubes.

Mr. SERUM. Yes. Yes.

Mr. CULBERSON. Because they make photo cells up to 60 to 70 percent efficient.

Mr. SERUM. By the way, I post-doc'ed at Rice in 1970.

Mr. CULBERSON. Did you?

Mr. SERUM. Yes.

Mr. CULBERSON. Did you work with Dr. Rick Smalley? Was he there at the time?

Mr. SERUM. Oh, yes. He was an undergraduate partner of mine.

Mr. CULBERSON. Did you get to meet him?

Mr. SERUM. Yes.

Mr. CULBERSON. Extraordinary, brilliant man.

Mr. SERUM. So I think that making real headway in many of these areas, cyber security, making sure that all the transactions that are conducted on the internet are really secure, personal identity protection, things like that. Those are all easy to say. They are not so easy to implement. And a lot of effort has to go into them. And if it were, if it is up to me I am consistent with those priorities that have been established.

Mr. CULBERSON. And then before I move on to Dr. Avery, are the research, is the research work done by NIST awarded, peer reviewed, competitively based research grants?

Mr. SERUM. I want to make sure I understand you correctly. Do you mean like the National Science Foundation?

Mr. CULBERSON. Yes. Do you all farm out the grant money? Is it——

Mr. SERUM. No. Mostly not.

Mr. CULBERSON. It is all done in house by in house scientists?

Mr. SERUM. It is mostly in house or partnered. If, for example, since you are very interested in nanoparticles, I have been quite insistent that they do not develop a whole toxicological department for that. But they partner with some world class organization to do that. They are the measurers and the developers of the technology and so forth.

Mr. CULBERSON. Right. Texas Medical Center is ready to do that, through the Alliance for Nano Health.

Mr. SERUM. All right.

Mr. CULBERSON. They have got a huge patient base, as well.

Mr. SERUM. So they will either do it themselves or they will partner to do it. And that is primarily their approach.

Mr. CULBERSON. Thank you. Then Dr. Avery, very quickly if you could, and then Chairman, I may, I may have one brief follow up after the Chairman. How should NOAA use the stimulus money?

Ms. AVERY. Okay. So we talked about the computation of resources.

Mr. CULBERSON. Yes, ma'am.

Ms. AVERY. And, you know, in many ways you get the petaflops necessary to do the job with the right architecture. And how you get there, the cheapest way is probably what you need whether it is contract or elsewhere.

Mr. CULBERSON. More computing power?

Ms. AVERY. Yes. More computing power, right architecture, satisfy the research needs. That is basically what you need. And the other areas for, in terms of facilities, certainly NOAA's ship, its research ships, could use an upgrade. And clearly the ocean observing system that they are poised to put in place would be another area that one could look at. And, I would also take a look at what other facilities that need major renovation that would lead to enhanced research services and operations.

Mr. CULBERSON. What about the satellite that was lost, number one?

Ms. AVERY. Okay, yeah.

Mr. CULBERSON. And number two, why doesn't NOAA or NASA carry insurance on those satellites like the Europeans do?

Ms. AVERY. Oh, I do not know. Self-insured, government self-insured, I guess. But that is the other question on the facility thing. Is it also for rescuing some of the satellite programs that have been lost? Or making sure that the satellites get up? I do not know if there is a separate budget in the stimulus package for the satellite programs or not on that.

Mr. CULBERSON. Thank you. Thank you. I have one extra area but I will wait until you are through. Or whenever you want me to do it. May I? Thank you, you are very gracious. The Chairman really is very generous with the time and it really is a joy working with you on the sciences. He knows how passionate I am about the sciences.

Ms. AVERY. That is great.

Mr. MOLLOHAN. It is obvious.

Ms. AVERY. It is obvious.

Mr. CULBERSON. And, do you remember in the movie "The Graduate" where the young man, remember Dustin Hoffman they said, Mr. Chairman, at one point, the father of a friend approaches him and said, "Young man, the word is plastics." Today, if that movie were remade the word would be nano.

Mr. SERUM. I agree.

Mr. CULBERSON. No doubt. It will be nano in everything we touch, see, and hear.

Ms. AVERY. Can I interject?

Mr. CULBERSON. Yes, ma'am.

Ms. AVERY. On the nano piece. There is a wonderful opportunity for a NIST/NOAA collaboration associated with the nano particles and the toxicity. Because it is not just toxicity to humans. It is also a real concern, I think, in the ocean sciences community of how these particles, if they get into the ocean, how they interact with a very unique life environment.

Mr. CULBERSON. No question.

Ms. AVERY. And so the marine side is, in toxicity——

Mr. CULBERSON. Let me say at the outset, there is absolutely no evidence that it is toxic to anybody.

Mr. SERUM. No.

Ms. AVERY. Absolutely not.

Mr. CULBERSON. Because they are so small. I do not want to leave the Chairman or the Committee with the wrong impression. It needs to be explored.

Ms. AVERY. That is right.

Mr. CULBERSON. Because it is brand new.

Ms. AVERY. That is right.

Mr. CULBERSON. There is zero evidence, unless you, you know, it is like with Sweet 'n Low. Unless you inject the poor mouse with about a gallon of Sweet 'n Low it might be toxic.

Mr. SERUM. Incidentally, there is a, the Hollings Marine Biology Group in South Carolina, in Charleston, is, we went down there this past year and did a full day review on the work. And they are doing just outstanding cooperative work. It is an excellent relationship.

Mr. CULBERSON. Well, if I could, Mr. Chairman, the one area I want to explore and then I will pass, and you have been so kind with your time, in light of the fact that we do know that the oceans are responsible for absorbing up to 90 percent of all carbon in the atmosphere. The oceans, you know, the good Lord designed this natural sink, and the dust storms, Mr. Chairman, off Africa a scientist I think at Woods Hole?

Ms. AVERY. Yes.

PLANKTON BLOOMS

Mr. CULBERSON. Noticed that whenever there was a dust storm in Africa and it blew all that dust out over the Mid-Atlantic that there were these huge plankton blooms. Because it is my understanding that a cubic yard of mid-ocean water contains less life than a cubic yard of Sahara Desert sand. Is that roughly correct?

Ms. AVERY. Yes.

Mr. CULBERSON. Because that is why the water is clear. And when the dust settled in the ocean the plankton bloomed. He noticed that there was this vast reduction in carbon dioxide, release of oxygen. He put two and two together. And I have been following this closely. I have been a subscriber to the journals Nature and Science for about twenty years. And he was unable, of course, to get permission from the United States. So he went to Peru, off the coast of South America, rented an iron, a freighter. Put powdered iron ore in it, and hired some guys I guess with snow shovels, Mr. Chairman, like a lawn fertilizer. And just drove back and forth over the ocean. And correct me at any point if I am wrong. And just fertilized the ocean off the coast of South America. Measured the results, and it was dramatic.

And correct me again if I am wrong. But I do not remember his name, I would love to know his name, number one. And we are going to have hearings week after next on climate change. But if you could tell us, the Chairman in particular, the scientist's name? And then correct me if I am wrong. He says that if you give him a tanker of iron ore he will give you an Ice Age. You know, and he is very serious about it. I mean, you really have to be careful with this stuff. So carbon sequestration is a terrific idea. We are trying to get, you know, the Chinese? They could care less. They are building vast numbers of coal, they have doubled, the Chinese have doubled the amount of carbon dioxide they are pumping into the atmosphere in ten years. And if you look at a satellite image, Mr. Chairman, of the, taken over the Pacific Ocean, look at the pollution bloom? It is appalling. I have had friends that went to China that are runners? They cannot even run in any of the cities in China. The pollution is so bad you cannot see across the street.

So the Chinese are pouring out carbon dioxide. We are not going to get them to do it. The Indians are pouring out carbon dioxide. You know, we really need to be careful before we handcuff America. But in the meantime, when we are debating that, could you please tell the Chairman about the work that Woods Hole has done on fertilizing the ocean using, and again, nanoparticles of iron oxide, you do not have the acid problem.

Ms. AVERY. Yes.

Mr. CULBERSON. The plankton can take it up more quickly. There is no acidity. I have already had Rice University graduate students helping me look at this.

Ms. AVERY. Yes.

Mr. CULBERSON. And I would very much, Mr. Chairman, if I could I will throw out an open ended question and then close. I like, if I could, Dr. Avery to help work with us during the carbon, the week that we have some hearings on climate change. Come talk to us about carbon sequestration, in particular fertilizing the ocean. That is a natural for NOAA to do and Woods Hole is the world's expert on it. Talk to us about fertilizing the ocean and what effect that can have as a carbon sink and helping us reverse the carbon in the atmosphere, and how careful we have to be because we could trigger an Ice Age.

Ms. AVERY. Okay. I think, first of all, Woods Hole's effort in all of this, of course, is to understand the underlying basic premises or processes associated with the idea of iron fertilization as a means for carbon sequestration. And there is still a lot of work to be done. Research currently is focused on whether iron stimulates a bloom. And as Mr. Culberson said, it does.

Mr. CULBERSON. My description was accurate.

Ms. AVERY. Yes. It stimulates a bloom. There is no question it stimulates a bloom. Where there has, where the research has not taken us yet, and where we do not know, is whether the carbon is ultimately buried and for how long it remains buried before it might come up again. And that is sort of the next stage of research that needs to be done. The other thing that needs to be done is taking some of these what we would call small scale pilot examples.

Mr. CULBERSON. Like the fertilizing the ocean off of Peru.

Ms. AVERY. Like off of Peru. What happens when you expand it to larger scales? Industrial level scales? That particular question has not been answered. WHOI did do, sponsored a workshop.

Mr. CULBERSON. Who?

Ms. AVERY. WHOI, the Woods Hole Oceanographic Institution. I am sorry. I speak in acronyms and I should not.

Mr. CULBERSON. Thank you.

Ms. AVERY. We call it WHOI.

Mr. CULBERSON. Thank you.

Ms. AVERY. We did do a workshop about a year and a half ago, or a couple of years ago, bringing a number of experts together to just focus on the iron fertilization issue to try to get it all out on the stage. What has worked? What do we know? What do we not know? What needs to be done? And there is a report on that workshop that we published in our Oceanus. So I will be happy to get that to the Committee because I think it is a very nice, done in public understanding language that would be helpful. And then I would be happy to give you a list of some of our scientists who might be able to come and really talk to you in more detail.

Mr. CULBERSON. Week after next?

Ms. AVERY. Yes.

Mr. CULBERSON. Week after next, and this finally, ten seconds, just this could be an area I think, Mr. Chairman, if we could look at giving some money, designating money within NOAA to help do this research as a really important way of getting carbon dioxide out of the atmosphere very rapidly. And I think the plankton, they all, it turns to limestone.

Ms. AVERY. Yeah.

Mr. CULBERSON. It is buried forever.

Ms. AVERY. The question is how it gets buried. Yeah. I do not know if it is going to stay there forever. We do not know yet.

Mr. CULBERSON. Thank you, Mr. Chairman, for your indulgence.

Mr. MOLLOHAN. Thank you, Mr. Culberson. Welcome, Mr. Ruppersberger.

Mr. RUPPERSBERGER. Sorry. We have other hearings also, so you try to jump from one to the other. How is your friend WHOI doing, by the way?

Ms. AVERY. My friend WHOI is doing well.

RESEARCH AND NOAA BUDGET

Mr. RUPPERSBERGER. Okay, that is good. The one, and only just one question, and if it has been addressed then just let me know. In your prepared statement you describe the inequity between the dollars allocated for research and the rest of NOAA's budget. And that has been a trend for a while, and it is unfortunate but hopefully we will be able to turn that around. In your opinion, do you think NOAA is capable of adequately addressing some of the most pressing issues, I think, of what we deal with in this country, if not the world. Which includes the impact of climate change on sea levels, drinking water supplies, and our environmental concerns that can impact the entire world. If you could address those three, and if you feel, again, the question, do you feel that NOAA is capable, if more money, money does not always solve a problem.

Ms. AVERY. That is right.

Mr. RUPPERSBERGER. And you have to have your priorities, you have to have your staff in place. And so if you can get into a little bit of detail on those three?

Ms. AVERY. Yes. The answer to your question is yes. But NOAA cannot do it all internally. NOAA has to basically make sure that, in tackling these problems, it puts together the expertise base from the entire country, if you will, to actually tackle some of these problems.

Mr. RUPPERSBERGER. That is pretty broad. What do you mean by that?

Ms. AVERY. Well, what I mean by it is, you know, NOAA has its, I talked a little bit about this, it has its own in house research scientists group. But it also partners with universities in getting additional expertise and collaboration on some of these.

Mr. RUPPERSBERGER. And that is a very good point.

Ms. AVERY. And that is a very important strategy. And so NOAA's research, if you will, is almost leveraged in many ways by seeking these partnerships throughout the country that allow them to leverage those facilities, those minds, that expertise, that student base, etcetera, to tackle these problems. But yes. NOAA can play a tremendous role in the adaptation agenda. The climate impacts and adaptation, your issue of sea level rise. An important sort of modeling effort, observational effort, that is needed. A process understanding with the thermal expansion of the ocean, getting that pinned down a little bit more. Its work with stakeholders on some of these issues is going to be critical in investing more effort into some of the regionally integrated science assessment and similar programs that they already have there would be useful.

Mr. RUPPERSBERGER. You talked about academia, which I think is extremely important. Those partnerships. And you can do a lot of the research that is needed in those arenas. And a lot of the people in the colleges are going to be our future people working in this area.

Ms. AVERY. That is right.

Mr. RUPPERSBERGER. How about in the business community?

Ms. AVERY. Yeah. I think, you know, NOAA has been, actually NOAA has developed a real nice partnership, or it has evolved. And there is always a little bit of tension. But it is really working very well now with the private sector. And they have done a lot of work with the value added that is associated with the private sector. You know, when we talk about a national climate service and how it can reach any number of sectors of decision makers, there is probably a very key role for the private sector in producing what we would call value added information and working with that, with that service with the research community to develop that. You are going to need to have some discussions on, and policy discussions, on what is sort of a public service and what belongs in the private sector.

Mr. RUPPERSBERGER. When you are an appropriator, or you are an administrator, or whatever, there is not enough money for everything. So, you know, you have got to look at requests, you have got to prioritize and then decide where you go. And sometimes you cannot do it all. But if you were to, if you were appropriator and you were focusing on NOAA, where would you prioritize the money to go?

Ms. AVERY. Oh, man.

Mr. RUPPERSBERGER. Knowing that, well, you are the expert and knowing that they, knowing that you need staff, you need the infrastructure and the resources probably that exist already so that we can make sure what we do do we do it the right way. And after that I am finished.

Mr. MOLLOHAN. Well, there is always Woods Hole.

Ms. AVERY. Yeah, really. I can think of triple the budget. Are you, that is a big question. Do you, can I narrow it?

Mr. RUPPERSBERGER. Can your friend WHOI handle that?

Ms. AVERY. WHOI could handle that, yeah. Or some of it. We would probably reach out to others, though. Are we talking about in the research house specifically? Or do you want me to get——

WATER SUPPLY

Mr. RUPPERSBERGER. Why do you not talk about the issues of sea level, drinking water supplies, and the environmental impact on other countries in this hemisphere, in South America and Canada, and where does the wind go. You know, I happen to be from Baltimore but I understand all of our bad air comes from Ohio.

Ms. AVERY. Well, certainly sea level rise is a critical research area and there is a critical need to get the observations that will help us understand better the processes associated with sea level rise. As we all know, the accelerated ice melt in the arctic is a key sort of climate issue that impacts us all. The research area associated with sea level rise and why, we are perhaps, not capturing that adequately in models yet, is probably associated with the dynamics of the thermal expansion of the oceans. And we do not have enough observations to actually help us with that. So that is a key question that gets to can I do sea level rise, and how are my coasts going to respond to sea level rise?

The drinking water, key, and the National Integrated Drought Information Service was one step but the whole issue of looking at water resource availability and being able to work with models that help decision makers, help cities, help agriculture people decide how you are going to manage water in the, fresh water in the future is, again, a key thing that NOAA could be doing. And environmental quality in general is going to be key.

Mr. RUPPERSBERGER. Okay, thank you.

NIST

Mr. MOLLOHAN. I want to revisit just a little bit the line of questioning that I was pursuing with you and Dr. Serum before the vote. Staff handed me the quote from Dr. Marburger last year and let me just read it. "NIST is a focused, well managed agency that ought to be about four times bigger than it is, in my humble opinion. And although it is a small agency that is why it features in the President's American Competitive Initiative. And that priority has been embraced in the America Competes Act and by others. So I would start with NIST." And the question was, where would you spend additional money for science research if you had additional money? So that was quite a ringing endorsement for NIST.

Mr. SERUM. Yes.

Mr. MOLLOHAN. And you were sounding just like Dr. Marburger did when you were answering my question. I do not know whether you had finished and I think I interrupted you in the middle of your answer. So, I wanted to give you an opportunity to elaborate on that. If we are going to increase spending for research in the area of science, as this administration has signaled it wants to, then we would like to hear every case made for different research opportunities.

Mr. SERUM. Yes. So, just continuing, I think that, you know, I started out by saying I think that the budget could be doubled immediately and they would know how to deal with it. There are a couple of things that are important there. NIST is an unbelievably conservative organization. It goes through the management of their funds as well as their self-aggrandizement in the publicity, and so forth. And I used to complain about that. But the fact is that their response was, if you cannot measure it then you had better not brag about it. And if they cannot exactly measure the contribution, which I felt was enormous in many industry segments, then we should not speak about it. So they are very careful. And in that carefulness and that conservative approach, they manage, I have observed them in my ten years managing on the up side of money and on the down side of money very effectively. And when, I think the last two years they were on a continuation budget most of the time. And I watched them reprioritize to make sure that the most critical programs were moving ahead as planned and as committed.

Their ability to respond quickly, I can think of two things. One is the World Trade Center bombing in which NIST immediately dedicated resources to not only understanding the cause of the collapse, and on our review board we went through that in gory detail, in which they recommended whole, entire new tower structure construction regulations or guidelines in order to accomplish that. That was not on their vision plan. The American Voting Act, or whatever the official name was, how do you, every American has the right to vote, you want to make sure that all the votes count correctly and just once. And that is a question of accuracy of voting machines. They jumped into that and immediately made recommendations for it. Those are not, that latter one is not large. But it is an example of how they can jump into something quickly and know how to deal with it and how to deliver a result.

As far as my priorities, when I look at energy, when I came into the Chairmanship I was thinking about where I would put my dollars if it were up to me. And in my, sort of my inaugural address on my first, in our first meeting, I spoke about the importance of energy independence and the many, many areas of contribution that NIST can make in that regard. And therefore, I would make energy, and again I say it goes to the measurement of energy. It goes to developing new sources. They have ideas on much more efficient solar panels. They have very good ideas on more efficient fuel cells, for hydrogen fuel cells. They have, they have been working in research on battery optimizing, or improving the performance of batteries so that the GM product when it comes out can get more then forty miles on a single charge. Those are critical to our energy independence. And I believe is very important for NIST to take on. And they recognize that. And they listed that in their three-year plan as one of the most important.

And again, I have not seen the number in the last year. But the amount we spend on healthcare is probably something like $1.4 trillion or $1.5 trillion now. It just, I can hardly even begin to speak to the impact that some of these diagnostic measures can make. At this international conference, bioimaging was determined to be one of the most critical contributions that one can make. NIST is doing several initiatives in bioimaging. The problem is one of sensitivity and specificity in order to do a diagnostic at the very, very early stage. And so NIST has the, if it were funded appropriately, NIST could probably make some significant contributions in bioimaging and that is one of the very important areas.

And I have already spoken about the field I have gotten into in the last fifteen years is really biotechnology, and understanding the role of both DNA, RNA and proteins in the cause of disease. NIST is working on structure function relationships and proteins for understanding that kind of disease. Each one of these has absolutely a stochastic impact on human health, quality of life, and so forth.

Mr. MOLLOHAN. Let me ask you to focus that just a little bit. If NIST were to receive additional funding, which you already have and if the President's signaling is an indication we can expect additional requests for funding, prioritize, say, through the top three or four what you think would be appropriate. Two, three, or four areas that you feel that that money ought to, where that money ought to go.

Mr. SERUM. Well, as I mentioned, and let me just——

Mr. MOLLOHAN. You mentioned a lot of different exciting areas.

Mr. SERUM. I would, let me say one other thing in a moment, is when one lists climate change, and energy, and infrastructure, and manufacturing technologies, and so forth, it is certainly true that NIST cannot do all of those with a high degree of quality. So I think that one of the challenges that I listed in our annual report that you will be getting almost momentarily, I made the recommendation that they had to prioritize those according to, one, their core competencies, two, according to their ability to make a significant contribution as measured by the impact on competitiveness or the economy.

Personally, I believe that energy is at the top of that list. And I would probably say, I would rate healthcare next. Now, they have a huge impact to make on infrastructure as well. I pooh-poohed their work in cement standardization when I first got involved. Well, if you look now at what is wrong with our infrastructure it is that things like cement are falling apart. And NIST has some initiatives underway that look at new standards to assure that cement bridges that are constructed now will last to a much greater time into the future.

NIST has underway initiatives that they want to expand on with regard to catastrophic weather damage. How do you construct a building on the Gulf Coast so that it is actually resistant to hurricane?

Mr. MOLLOHAN. Well, I am looking for the priority. But you are suggesting that, your prioritization. But you are suggesting that this report that will do that is imminent?

Mr. SERUM. What we did, they listed about six areas. And our statement, my statement was that they should go back and reassess that. They stated that in their three-year report and they did not prioritize those six. My statement was they cannot, they do not have the same core competencies in all six. The impact of the outcomes is not the same in all cases. And therefore, I asked them to go back and reevaluate those on the basis of those parameters.

INVESTMENT IN SCIENCE

Mr. MOLLOHAN. In your judgment, should we be investing more in broader science and technology programs, STRS, and less in MEP and TIP? I ask with foreboding.

Mr. SERUM. I have a bias there. And my answer to that question would be yes. If it were up to me I would put dramatically more money into the laboratory research. Now, that is not to say that I do not support TIP and MEP. They serve a different purpose. As consider MEP. As one looks at U.S. competitiveness, and I cannot remember the exact number but something like 80 percent of our businesses are small businesses, or 80 percent of the employees are small businesses. And the sole purpose of MEP, Manufacturing Extension Partnership, is to transfer technology, know-how, et cetera, to make them more productive, produce products at a lower cost, and so forth. That is a, that is a well run, historic organization that in my opinion is doing very well. I would not personally add a lot of money to it. But I for sure would not eliminate it given our national goals.

The TIP program, the Technology Innovation Partnership, is new.

Mr. MOLLOHAN. Well, it was called the——

Mr. SERUM. But it has changed.

Mr. MOLLOHAN [continuing]. ATP program, I believe.

Mr. SERUM. Yes, it was ATP. But very much different and focused virtually 100 percent on innovation now.

Mr. MOLLOHAN. Is now.

Mr. SERUM. Is now, yes. And I believe that is a very good foundation to continue to support. But I would, and you know, I think it is, it could probably grow some in its budget in order to advance some of the fundamental high risk, high reward type technologies. But that said, that is not where, if I were Marburger I would not put, I would put the vast majority into STRS laboratories.

Mr. MOLLOHAN. He is just recommending, too.

Mr. SERUM. Yes. So, you know, there are not very many places, in fact, I am sure there are no other organizations in the world that can boast three Nobel Prize winners in their organization.

Mr. MOLLOHAN. Yes, that was very impressive. Dr. Avery, thank you. Thank you, doctor, sir. Although NOAA's primary responsibilities are operational, do a lot of research, we have talked about that a little. There was a line of questioning about inside research and contract research. I just want you to elaborate a little bit. From your perspective as a member of the science community, the research community, outside NOAA, is the balance between in agency research and outside research in your judgment a good balance, a correct balance? Does it need to shift one way or the other? And if you would, elaborate on why.

Ms. AVERY. Sure. Yes, this has been sort of an ongoing discussion about the appropriate balance between internal and external research, or in house and outside research. You know, currently I think the balance is about 70 percent in house, 30 percent outside. There has always been a goal over many administrations and under many NOAA Under Secretaries is that it be a goal of 50 percent, 50 percent.

You know, when you look at what is in house expertise and external expertise what you are really doing is looking at the unique complementary attributes of those two communities. So if you look at the NOAA laboratories very much like the NIST laboratories, there is stability in the research agenda. There are long term missions that they satisfy. They have base funding. If you look at the external community and that external research portfolio you are looking at research that might be more agile, more closely linked to external international partners worldwide. You might be looking at leveraging funding from other agencies or assets that would, might be easier to do externally than in house. You might be looking for training for the next work force, or the ability to engage user communities.

So, what is the right balance? I do not know if you could basically set a specific number. What might be beneficial is for the agency to really sit down and have a discussion or to develop some sort of coherent policy or guidelines themselves on what they think is stuff that should be done internally and what should be done externally. Other mission agencies have had this discussion.

Mr. MOLLOHAN. NOAA has not?

Ms. AVERY. I do not think NOAA has specifically articulated that, at least to enough knowledge that it gets communicated widely. And that might be a good starting point to actually then determine what is the right balance.

Ideally, eventually, the balance is going to be determined and should be tailored to the particular problem that you are going to look at with the particular expertise that you need.

Mr. MOLLOHAN. Yes. To what extent does the expertise need to be in house, for example.

Ms. AVERY. Right.

Mr. MOLLOHAN. To what extent do you need to have in house expertise to even monitor the contract research?

Ms. AVERY. Right.

Mr. MOLLOHAN. Where does 50–50 come from? That sounds a bit arbitrary.

Ms. AVERY. I know it has been, for the last couple of administrations the number has always been, "Well, the new resources should be 50 percent external, 50 percent internal." I think it was trying to get a balance between the agility, if you will, to focus on a particular problem and bring in that expertise without bringing that, all the expertise that you need all the time in house, which could get quite costly. I mean, if you, if you look at the breadth of NOAA's mission and the science that needs to underpin that mission, and if you wanted all of the research to be done in house, you would be having a huge federal workforce, scientific workforce.

Mr. MOLLOHAN. That does not bother some of us.

Ms. AVERY. Well, yes.

Mr. MOLLOHAN. But others.

Ms. AVERY. The real question is, is when you make that commitment, have you basically then lost some agility that you might get that an external community provides.

Mr. MOLLOHAN. Well, Woods Hole is a contract out operation, is it not?

Ms. AVERY. It is a soft money organization.

Mr. MOLLOHAN. But you really think of it as a NOAA operation.

Ms. AVERY. Really?

Mr. MOLLOHAN. That may be very inaccurate, or it may be because I am not really familiar with it.

WOODS HOLE

Ms. AVERY. Now Woods Hole's history, initially, you know, seventy-five, eighty years ago, was based in Navy, and the Navy when the Navy really had the major oceanic research component. But then the Navy backed out of ocean research greatly, and particularly the deep ocean, greatly. At same time that the National Science Foundation then began to ramp up its budget for ocean science research.

Mr. MOLLOHAN. Mm-hmm.

Ms. AVERY. So WHOI—sorry, Woods Hole Oceanographic——

Mr. MOLLOHAN. No, we got it now.

Ms. AVERY. Got it? They are fast learners. WHOI's research portfolio, funding portfolio now, is predominantly, the largest source of research grants comes from the National Science Foundation. And then secondly, Navy and NOAA in about equal partnerships.

Mr. MOLLOHAN. Ah. So that is very appropriate to be an outside research organization. It works really well.

Ms. AVERY. It really does.

Mr. MOLLOHAN. You are able to work with other agencies. So maybe that is one of the tests, how many different research directions you serve.

Ms. AVERY. What that does is, it leverages the resources of all of those and the types of research that one does in a comprehensive way.

Mr. MOLLOHAN. It sounds like there is not, but in making these decisions, is there a criteria list that people look at? Or is it sort of intuitive as you are sitting around the table? Or do you know? You may not know.

Ms. AVERY. I do not know.

Mr. MOLLOHAN. O.K.

Ms. AVERY. I really do not know. I am not at that level of the organization.

NOAA FUNDING

Mr. MOLLOHAN. All right. If there is an increase in funding for NOAA, what should be the balance between operational needs, including critical satellite observations to address climate change, and increased support for research?

Ms. AVERY. Well, again, I will be biased just as——

Mr. MOLLOHAN. That is okay.

Ms. AVERY. In the fact that, you know, the research program, as has been noted, has been flat or decreasing for so many years. And there are so many issues that require that research underpinning that it is really needed. On the other hand, I am very sensitive to the need that the research enterprise needs observational data. It needs observational data both from an in situ observing platform as well as from a satellite observing platform. I also realize that part of NOAA's budget constraints over the last year, few years, has been sort of the cost overruns associated with their satellite programs. And getting those under control is obviously key. And——

Mr. MOLLOHAN. A couple of tough programs, hopefully lessons learned.

Ms. AVERY. That is right, lessons learned to go forward in the future. I would hate to say that the research program would continue to be not supported because we have the satellite program still to resolve. I would love to just get the satellite problem off the table and get refocused on NOAA's missions that need that science underpinning so badly.

Mr. MOLLOHAN. Just for the record, to give you an opportunity to say it, to talk about it, what would be the consequences, assuming levels of research funding at NOAA just simply remain the same, not decrease.

Ms. AVERY. Well, you are putting at risk several, sort of things. Like I said before, a lot of the observational work that is the underpinnings of the research component is actually being funded by the research program itself. And so if the, research program remains flat, or declines, you are putting at risk, if you will, not only the research but some of the observations to support that research. And ultimately, the innovation and creativity that is going to go into addressing questions of better weather forecasts, better hurricane prediction, climate adaptation, climate impacts, and ecosystem based management. So you are really, you know, you can only do, you can only stay the course so much and not having that research continually feeding, updating, upgrading, looking at new approaches, thinking outside the box when things are not working in a complex environmental framework. And that is basically what you are putting at risk.

Mr. MOLLOHAN. You all have been tremendous here today, first of all appearing and then secondly giving this good testimony. We had a few minutes off the hearing because of the votes, and so, we are going a little over. Perhaps we can keep it to one more round of questioning and give Mr. Culberson an opportunity. Then we will ask some fast questions and try to wrap it up. Mr. Culberson?

Mr. CULBERSON. Thank you, Mr. Chairman. I will be very, very brief, just to say that I am struck here again today with the expert advice of this panel which you have put together telling us that the best investment, it seems to me, from your testimony, the best investment of our dollars is always going to be in the pure scientific research, in the competitive peer reviewed scientific research, and just let the facts lead where they may. It is a tremendous, I think, place to invest our money.

I would actually just ask Dr. Avery, if I could, specifically, would you recommend then that this Committee, I see it was the conclusion, I do have an article here from the January 11 issue of the Journal of Science summarizing the, I guess you, a workshop that you call it? The work that you did at Woods Hole to talk about iron fertilization of the ocean?

Ms. AVERY. Yes.

Mr. CULBERSON. That your conclusion essentially was that we need more research, clearly.

Ms. AVERY. Yes.

Mr. CULBERSON. And we will find out what the effects are and how best to do it. Then, would you then recommend to the Committee that we ask, specifically task NOAA with conducting the research that has to be done? Because NOAA is the best place for it to be done.

Ms. AVERY. That is probably a good starting point, yes.

Mr. CULBERSON. You would make that recommendation to the Committee?

CARBON SEQUESTRATION

Ms. AVERY. Yes. If, certainly if you are looking at carbon sequestration as part of the portfolio——

Mr. CULBERSON. Right.

Ms. AVERY [continuing]. Of what we do with our energy environment. You know, our energy portfolio——

Mr. CULBERSON. Right.

Ms. AVERY [continuing]. As we go forward for an energy portfolio, it is renewables, there still could probably be, you know, offshore drilling at some level. There is going to certainly be the issue of carbon sequestration. When I talk to oil companies they are counting on carbon sequestration as one of their solutions. How that carbon sequestration is going to be done, whether it is in the ocean or on land-based systems probably needs——

Mr. CULBERSON. That really, forgive me, that actually was the question I intended to ask, Mr. Chairman. Is when, would the Committee, I was asking, give specific guidance to NOAA to look at carbon sequestration.

Ms. AVERY. Sequestration, yes.

Mr. CULBERSON. Department of Energy is probably going to have to also do the same thing.

Ms. AVERY. That is right.

Mr. CULBERSON. But looking at carbon sequestration, the specific part of that has got to be how do you encourage it in the oceans, which is 90 percent of the——

Ms. AVERY. Right.

Mr. CULBERSON [continuing]. Carbon sink on earth? Is this a, let me make sure I understood from your testimony, Dr. Serum. What are the core competency areas that you think NIST should focus on? We do not want you doing, NIST doing too much, too many things and not doing them well. I just want to make sure for absolute clarity. And my concluding question, if you could tell us the core areas that you think NIST should focus on? In its pure basic research. Work in establishing standards, for example, for concrete, which is a good example.

Mr. SERUM. Yes. I, first of all let me say that NIST views their core competency as accurate measurement in many areas. And indeed, I want to emphasize that very strongly. You can go into a new field, as long as you are dedicated to making accurate measurements and understanding the technology, or developing the technology that allows those measurements to be made accurately. Then you are making a major contribution. Whether it be in climate change measurements, which suffer greatly from accurate measurements. Whether it be in energy, related to new technologies or in things like the grid. So I would say the foundation is accurate measurements.

Now, the interesting thing is that I would say NIST has a good competency in healthcare. I would not say they have an outstanding competency in energy. But they know how to get that competency. And I think it is important for them to get that competency.

They have phenomenal, an area that I did not even speak of, it is almost more like a fundamental science, but the world, the next thing that is going to explode, also very small, is quantum physics. And I could speak to the benefits that quantum physics is going to have. But you are talking about the IBM computer. Quantum computing has the opportunity to do massive computing in a very short time, that even the biggest computers cannot do now over many years. That kind of work, it is really important to continue. That is where the Nobel Prizes are, by the way, in understanding all of that. And I have to rate that as a fundamental science that is vitally important to everything that goes on. I do not classify that as energy or something like that, yet it——

Mr. CULBERSON. That is within NIST's core competency?

Mr. SERUM. It is a very big competency of NIST. As now I would say nanotechnology two years ago was not a competency. I now believe it is a competency, and there is no lack of ideas as to how to move forward. But those, you know, it is a little difficult. You classify energy. I have spoken hardly at all about information technology. I would say that is a core competency from a technology perspective. Phenomenal talent and ideas in complex systems, cyber security, a variety of areas, that will make a contribution in these applications areas, such as energy and such as healthcare. The medical record that is a priority now. NIST will play a very major role in standardization of that information so it can move across. Very, very important.

Mr. CULBERSON. Thank you.

Ms. AVERY. If I could go back to your question about the iron fertilization and carbon sequestration in general, I think NOAA is appropriate but I am not so sure that NOAA should not be also working with DOE on this. And getting, whereas NOAA has the expertise, DOE probably should be aware of ocean opportunities, and the opportunities the ocean has to solving the energy piece.

Mr. CULBERSON. Bundled perhaps with power plant sequestration.

Ms. AVERY. Yes.

Mr. CULBERSON. Thank you very much, Mr. Chairman. Thank you.

NASA EARTH SCIENCE AND NOAA

Mr. MOLLOHAN. Okay. Thank you, Mr. Culberson. Dr. Avery, should ties between NASA Earth science and NOAA be strengthened? Or changed?

Ms. AVERY. It should be strengthened. I think that there has been certainly good dialogue in the past between NASA and NOAA at the working level. It is critical because, as I said before, a lot of research missions that are initiated within the NASA framework will, may ultimately end up in an operational context.

Mr. MOLLOHAN. How could it be strengthened?

Ms. AVERY. Well——

Mr. MOLLOHAN. And in what ways should it be strengthened?

Ms. AVERY. Yeah. I think what you can do is in part look at the decadal survey that was done, now how many, two years ago? Thank you. The recommendations there really call for the Earth, space-earth observation capability for the future, and regaining, if you will, the U.S. capability in that. The observing capability from space has degraded over the last decade. And they have specific recommendations on how that relationship can be strengthened, what kinds of things NOAA should be doing in this next stage, what kinds of things NASA should be doing, and how they might be partnering together to move things from research to operations.

Mr. MOLLOHAN. Where the hand off is, or where it is not.

Ms. AVERY. Right.

Mr. MOLLOHAN. And what the roles and the boundaries are.

Ms. AVERY. You know, part of the issue is that sometimes the research needs, sometimes you need to have missions to actually put it in a research framework to understand what is really needed for an operational framework, if I am making sense. So in other words, you do not necessarily know ahead of time what the exact operational framework should be. What kind of observations, where they should be, how frequently should they be measured, what is the distribution? And so often, NASA will start with looking at primarily a research mission that is focused on a particular research question that then helps inform, if you will, an operational strategy. If you know in advance that there might be a really great operational hand off here, it is probably not a bad idea to sit the research and operational agencies together to kind of at least acknowledge that there is that potential. Because very often you get in this, in this bind where a research satellite goes up and then all of a sudden the data becomes very, very useful to an operational entity. TRIM, the TRIM mission, which is a rainfall mission, was one of those. Yet, because NASA had deemed it as a research mission with a specific, specified timeline, or time life, lifetime, yet the operational entities were using it. Then there was an operational sort of push back, if you will, for a limited, you know, stopping this particular——

Mr. MOLLOHAN. Those responsibilities and those roles are not decided ahead of time.

Ms. AVERY. Not necessarily, because you may not know, necessarily, that it is going to have an operational value. It may just be that it is focused on a research endeavor. Because NASA is a fundamental research——

Mr. MOLLOHAN. I see.

Ms. AVERY. Yeah. So I think getting better at having that dialogue ahead of time when you are looking at a, particularly in earth observations from space, if you can have that dialogue that has the research community and the potential operational use. Have that dialogue up front so that you are at least cognizant of that.

Mr. MOLLOHAN. Yes.

Ms. AVERY. Then there might be a better, smoother transition.

Mr. MOLLOHAN. Have the agencies come to that?

Ms. AVERY. I think there is acknowledgment of that internally. I am not sure if it gets transmitted at the highest levels and in the budget process to actually have that happen.

Mr. MOLLOHAN. Down to the——

Ms. AVERY. You need dedicated people who are doing this full time, probably.

Mr. MOLLOHAN. So where is the issue? At the program level?

Ms. AVERY. I do not know.

NOAA AND DEPARTMENT OF DEFENSE RESEARCH

Mr. MOLLOHAN. Same question with regard to NOAA and Department of Defense research and environmental operations. Should it be strengthened? Changed?

Ms. AVERY. Yes, it should be strengthened. And again, the greatest intersection that I see there probably is between, is in the ocean area. The, and one example that would illustrate the NOAA-Department of Defense, primarily probably Navy, would be even what is happening up in the Arctic. If we are looking at, in the next decade, relatively ice free zones for a significant period of time, what does that mean in terms of resource availability, security issues, any number of things. And this is where NOAA and Navy could really have a good discussion and good partnership.

Mr. MOLLOHAN. Following up on Mr. Culberson's and your discussion, and maybe Dr. Serum's, about energy, and the notion of spreading, I suppose, powdered iron on the ocean as a CO_2 sink strategy, I guess. Is there a dialogue, a relationship with Department of Energy and the National Energy and Technology Laboratory, NETL, regarding that notion?

Ms. AVERY. If it is it is not a very active one. If you look at DOE's portfolio over the years, prior, you know, prior, well I am trying to think. There used to be in the DOE framework a look at the oceans and their energy potential. That sort of research portfolio, I am trying to think, probably was cut away and eliminated, or down scaled, probably during, I want to say the Reagan era. Eighties, eighties. And, you know, I actually was looking the other day at the DOE laboratories trying to figure out if any of the laboratories are putting any significant amount of work into the ocean and its role in the energy arena. And there is not a lot going on. And it is probably something that should be——

Mr. MOLLOHAN. There is not a lot going on in terms of collaboration?

Ms. AVERY. In terms of just research at all.

Mr. MOLLOHAN. Oh.

DOE LABORATORIES

Ms. AVERY. In the DOE labs.

Mr. MOLLOHAN. With regard to the potential.

Ms. AVERY. Ocean, the ocean and its role in the energy portfolio. I think it is something that would be very useful to have a discussion with DOE.

Mr. MOLLOHAN. Is that something Woods Hole specifically is interested in, or has a jurisdiction regarding?

Ms. AVERY. We do. We are very interested in it. We are very interested because we see the dialogue in ocean, you can see, you can talk about ocean in terms of energy derived from oceans in terms of tides. You can talk about it in terms of waves. You can talk about it in terms of currents. You can talk about it in terms of thermal extraction. You can talk about it in terms of carbon sequestration of the ocean. You can talk about it in terms of sighting of wind farms offshore. You can talk about it, also the energy portfolio, in terms of offshore drilling. How is the best way to do it, minimizing environmental impacts? A lot of things like that.

Mr. MOLLOHAN. I would think you would have a real collaboration. Everything we talk about in this hearing is about money. This is certainly about big money. Futuregen.

Ms. AVERY. Yes.

Mr. MOLLOHAN. I do not know whether it is a carbon sink but it is definitely a money sink. And there are huge amounts of money going there just, let us try this for half a billion dollars. Well, that did not work. Let us try this for half a billion. It seemed to me that consultations with regard to all of these ideas up front would be very beneficial, particularly what I have heard today about the potential of the ocean. I cannot speak for them, but I do not believe NETL is looking much at that. And if you are not talking with them, I do not know how they would look at it without talking to you. And also, the biological, the enzyme approaches to this issue and the little bugs they have described approach to this issue. I would think that you all naturally would be involved, or want to be involved, in that. I really commend that to you, and I am actually going to speak with them and hear them talk about that potential.

This is a huge issue. And just pumping CO_2 into the ground somehow, and such massive amounts of it, too. I mean, you have to have places to do it even if it is a good idea. But we are going to spend——

Mr. CULBERSON. Oceans. Oceans are sinking it.

Mr. MOLLOHAN. Yes, if there is a biological process that happens that is environmentally neutral or positive, I think that that would certainly have to be considered, the viability of it considered. And the cost benefit of it. You know, before we move forward. We are hey diddle, diddle right up the middle with carbon sequestration. I think that stepping back and thinking about it a little better in a multidisciplinary, multi agency way, I mean, that is something we should see how we could promote. And you may have some advice in regard to.

Ms. AVERY. Yes.

Mr. MOLLOHAN. So. Well on that note, energy, which is almost where we started I think, if Mr. Culberson does not have any more questions?

Mr. CULBERSON. Just thank you.

Mr. MOLLOHAN. Okay. And we may have some questions to submit to you. And you are not an agency, you do not have to answer them, but you might be kind enough to be responsive to them. I have a couple questions here that I might like for you to respond to. We very much appreciate your time and your expertise. You were very kind to come down here, or over here, or in here. Wherever you came from. Down here, Woods Hole, I am thinking north——

Ms. AVERY. North, yes.

Mr. MOLLOHAN. Thank you for your testimony. Today has been extremely helpful.

Mr. SERUM. Thank you.

Ms. AVERY. Thank you.

Mr. MOLLOHAN. Thank you.

Questions for the Record for Dr. James W. Serum

1. **NIST is positioned at the intersection of academia – which generates most fundamental scientific discoveries – and industry – which turns discoveries into products and services. What role can or does NIST play in exploratory and high-risk research proposals that can revolutionize fields of science and lead to radically new technologies?**

    - In reality, all organizations (Academic, Government, and Industry) contribute to research and scientific discoveries, but typically in a different way. Even when performing basic research in industry, it is oriented toward a product or service and cost to develop is a significant factor. Academic research has historically been focused on basic, fundamental discovery of science or technological fundamentals. In recent years, however, a significant amount of academic research is also outcome oriented due to funding constraints. Government research should normally be focused on long range, very challenging research which has very high societal or economic importance and where a company or even a collection of companies believe that the risks are too high and the financial investment to great to take on the challenge. In addition, government research labs should focus on technologies which span multiple industrial segments and have the potential to benefit a broad number of companies and people. For example, Information Technology research discoveries will often impact nearly every segment of society. Healthcare based discoveries have a similar impact.

    - In general for NIST, its unique role is to advance measurements, standards, and technology so that the next innovation can be realized and commercialized. In other words NIST provides tools and expertise to enable other scientists and engineers to further advance their high-risk research which can eventually lead to radical new technologies. NIST provides the foundation upon which high-risk research can be built upon.

2. **Following the *Rising Above the Gathering Storm* report, there has been a bipartisan effort to double the budgets of NIST, NSF and DOE Office of Science. The President's 2010 budget provides significant increases for NIST in addition to funding provided in the Recovery Act.**

    a. **What effect is this having on NIST programs?**

    - The VCAT (Visiting Committee on Advanced Technology) which I currently chair, has long felt that NIST is dramatically underfunded to realize its potential contribution to our nation through development of standards, advanced measurement systems, and innovative technology. The VCAT members expressed gratitude in their Annual Report to those who approved funding according to the doubling goal. There are many more relevant ideas and exploratory feasibility studies undertaken than can be funded to be utilized by industry and society for improved industrial competitiveness. The increased funds to achieve the goals in America Competes Act are very welcome. It is my understanding that many of these funds will be utilized for launching initiatives in Healthcare, Energy, the Environment, our nation's Infrastructure, and Homeland Security. In most cases, NIST has some expertise in place for these research projects but insufficient resources and funding to have previously launched the feasibility initiatives. The new additional funds will enable some of the most promising ideas to be launched as technology feasibility projects. In addition, important projects which have lacked sufficient funds to achieve critical mass can now be funded for success.

- There is a saying "What you can't measure, you can't control and what you can't control, you can't reliably manufacture". The key core competency of NIST is "accurate measurement technologies". For example, measuring the effect of the temperature of the sun on climate change requires extremely accurate measurements by optical devices on satellites. NIST is the only organization to my knowledge that has the understanding and core competency to make this type of measurement. These types of accurate measurements are fundamental to many of the technological challenges that our country faces in the next several years. Another example can be found in the Healthcare industry. Imaging, both optical and chemical, are believed to be crucially important to advancing the health of our citizens, yet due to both sensitivity and specificity measurement barriers, we are not currently able to advance this technology sufficiently to meet our needs. I believe that NIST is in an outstanding position to make these types of significant contributions to the nation's priorities during the next few years. These additional funds will enable at least some of them to progress through initiatives and be implemented. This applies to both critical standards and advanced technologies.

b. What steps can NIST take to ensure that funding increases and concomitant employment is sustainable over the long term?

- NIST serves a huge diversity of industrial segments and a broad spectrum of customers. They must focus on management decision processes that enable the senior staff to prioritize those programs that have the greatest potential for industrial success or contribution to society (e.g. Healthcare initiatives). VCAT has been critical of NIST in recent years for lack of a comprehensive Strategic Plan. With the great diversity of industries which they serve and the almost unbelievable number of opportunities to contribute to the Nation's key issues, a strategic plan is very much needed at this time. The organization has made significant advancements in seeking out the "voice of the customer" to clearly identify their needs and then developing programs that address these industrial needs. An excellent example of this is seen in the jointly hosted conference last October to assemble Bioscience experts who could answer the question of the greatest measurement needs in Bioscience in the 21st Century. They have digested the data and have developed a preliminary report that provides the foundation for a Healthcare strategic plan.

c. Is there a tipping point with respect to funding and responsibilities beyond which NIST ceases to be effective? How can we ensure that we do not exceed NIST's capacity?

- NIST makes outstanding use of Post Docs both as a source for future employment and as a mechanism to manage resources in a volatile financial environment. In my opinion they have done an outstanding job of maintaining momentum during the past couple of years when they had to operate within a "continuation budget". The key to making the desired technological contributions yet maintaining a sense of caution will be to evaluate necessary expertise competencies to achieve their goals and then surround them with post docs and external partners to make it happen but still have flexibility. As indicated earlier, I am confident that NIST has many more excellent ideas and promising early research evidence than they have money to implement the programs to their completion. I believe that NIST could respond rapidly to additional funds and responsibilities. Evidence for this is seen in their work on the America Votes Act and their world class work on understanding and improving building design based on the September 11, 2001 disaster. They also responded rapidly to that disaster with human remains identification using their expertise in DNA assays.

- It is my opinion that NIST could easily have their budget doubled in the short term and they would be able to effectively apply the funds to critically important research for US competitiveness and economic growth.

3. How can we maximize NIST's role in the development of future scientists and mathematicians with respect to postdocs, research fellowships, science education, teacher training, and the construction of research science buildings?

- I was involved in the NRC Council for Undergraduate Science Education for many years so this question is one of interest.
- NIST has numerous partnerships such as with JILA at the University of Colorado, Hollings Marine Research Labs in South Carolina, and the Center for Advanced Research in Biotechnology (CARB) with the University of Maryland. These involve both undergraduate and graduate students. JILA has been in existence for many years and is a proven model of success in education and advanced research. Students coming out of the JILA program have been recognized internationally for their own subsequent research. Additional partnerships at NIST such as these, in relevant areas could be an excellent approach to accelerating science and technology education
- NIST conducts a wide variety of seminars, conferences, and workshops related to standards, techniques, and technologies. NIST has an extensive post doc program for working within NIST. This not only helps to educate the individual but also facilitates the transfer of standards, methods and technology when the individual moves to industry.
- NIST fellows are active in their scientific communities and frequently lecture at universities and seminars on their research.
- It would be worthwhile to hold a work session at NIST on the specific question described above. I think that there would be great interest in participation and could lead to a number of novel approaches to utilizing the expertise of NIST professional staff in formal education of undergraduates and graduates.
- NIST has a number of formal programs to further the education and training of undergraduates, graduates and post-doctoral students. These are outlined in question #4 along with recommendations for strengthening those programs.

4. Please describe NIST's programs in science, technology, engineering, and mathematics education and how they should be strengthened?

- NIST has extensive educational programs related to the advancement of standards and technology both nationally and internationally. To the best of my knowledge, there is no integrated plan across the organization that focuses specifically on the education of our young scientists and engineers. Many of their educational programs are focused on the transfer of knowledge, standards, and technology for the purpose of advancing their mission which is to promote industrial competitiveness by the advancement of science, standards and technology in a way that advances economic security and improves the quality of life. It would be interesting to reverse the question and examine whether some of these programs could serve dual purposes.

- That being said, NIST does have several programs that are focused in part or in whole on STEM Education. These include:

  - Post doc program with the National Research Council. This program provides two-year temporary appointments for outstanding scientists and engineers chosen through a national competition. These appointments provide an opportunity for some of the nation's best young scientific talent to engage in research with senior researchers at NIST. Currently NIST only has funding for about ½ the number of Post doc's it is authorized to support, so more funding for this program would definitely strengthen it.

  - Summer Undergraduate Research Fellowship is a partnership with NIST, NSF, and participating colleges/universities. Undergraduates students spend their summers working at one of the NIST laboratories. This program has been tremendously successful and continues to grow every year so I would not recommend any changes.

  - Summer Institute for Teachers is a program NIST recently began with the local school district in Montgomery County, Maryland. This program provides STEM teachers with an innovative combination of hands-on activities, lectures, tours, and shadowing of NIST scientists in the labs in ways to enrich and enhance the science curriculum. My understanding is that this program is very small and could be enhanced with additional resources to further develop the program's materials and to allow additional school districts to participate.

From: Rep. Robert Aderholt
Re: FY10 CJS Appropriations Subcommitee Hearing Questions
Date: March 4, 2009 – 2:00PM

Serum Testimony:

1. Global competition among businesses increases year after year and the United States continues to lose manufacturing jobs to overseas companies. In what ways can the Manufacturing Partnership (MEP) program help American businesses stay competitive?

Response:

- The charter of the MEP is to help American businesses be more competitive. A major challenge for small businesses throughout the US is to rapidly adopt new technologies and processes which provides for greater production efficiency, higher product quality and reduced manufacturing costs. The MEP network involving NIST, as well as state and local governments, provides training and technical and process advisory expertise to assist in more rapid adoption of these new technologies and processes, allowing them to be more competitive with new technology and with greater efficiency at a lower cost. In addition, NIST has established standards for a broad variety of manufactured products that small and large companies can incorporate into their processes that enable broader market acceptance and higher product quality. Technology advancements are occurring at an ever greater rate and the adoption of "green" technologies will enable some companies to have preferential market acceptance. The MEP program facilitates US companies access to these new technologies at a more rapid adoption rate thus enabling them to be more competitive.

2. You refer to NIST's measurements and standards being integral to the success of great engineering achievements such as automobiles, computers, and the Internet. What future major accomplishments can you envision NIST having a role in?

Response:

- Scientific and technological innovation depends heavily on a foundation of being able to make accurate measurements and in the utilization of concise standards for scientific experimentation and in making products. This is due to the fact that many advances in understanding are very subtle with small experimental or parametric changes being the critical factor for the advancement. When one thinks of the major technological initiatives in Energy, Healthcare and the Environment over the next 15-20 years, NIST can and should play a major role in each of these important technology segments. For example, with regard to climate change, more accurate measurements are needed in order to better understand the global impact of CO_2 concentration and its sources, the temperature of the sun, and other contributing factors. NIST understands how to make these measurements more accurately and has already been involved in contributing to the better understanding of this important problem. In the Energy segment, the US needs to find ways to incorporate the new sources of energy such as wind, solar and other new technologies into the overall energy grid. These energy sources are not constant as in our historic hydroelectric and coal fueled power plants and must therefore incorporate new methods for supply and transmission. The "Smart Grid" is an excellent initiative for developing these new methods but new standards must be developed across the entire grid from energy source, through transmission into the home and factory. NIST has been given responsibility for establishing these "standards" (Energy Independence Act of 2007) and I believe it is a vital element for achieving energy independence in the US over the next 15 years. In the area of Healthcare, both measurements and standards are critical to advancing new technologies. I have testified about the complexities of biological pathways in understanding of the cause of diseases and about the challenges of sensitivity and specificity involved in making significant progress in imaging technology. Advancements in both of these areas require highly sophisticated new approaches to accurate measurements as well as standardization of methodology to allow broad acceptance across the industry. In addition, the Electronic Medical Record has the capability of dramatic improvement of the quality of healthcare as well as the potential to significantly reducing costs. Standardization of communication protocols for the EMR with high security is paramount to the acceptance and use of the EMR. NIST is in an excellent position relative to expertise and experience to drive these standards for Healthcare.

THURSDAY, MARCH 5, 2009.

SCIENCE EDUCATION

WITNESSES

BILL NYE, "THE SCIENCE GUY"
DR. HAROLD PRATT, FORMER PRESIDENT, NATIONAL SCIENCE TEACHERS ASSOCIATION

OPENING STATEMENT BY CHAIRMAN MOLLOHAN

Mr. MOLLOHAN. The hearing will come to order.

Good morning, Mr. Nye and Mr. Pratt. Science, technology, engineering, and mathematics or STEM are key to U.S. economic growth and STEM education is key to the continuing health of the U.S. science enterprise.

I first want to welcome both of our outstanding witnesses here today. We look forward to their testimony. Between them, they bring us a wealth of knowledge over a broad area, enlightening us today, I am sure, on science, science and math education and how the resources that this Subcommittee appropriates will be best applied to advance that cause.

I would also like to notice and welcome the large group of students here today. They are from the National Young Leaders Conference; is that right, students? Yes. They are from the National Young Leaders Conference. We welcome them.

And after today, they may be seeking professions in science, who knows, in great numbers. We certainly hope so. That would be one additional good outcome of this hearing.

Well, this week, the Commerce, Justice, Science Subcommittee, which is this Subcommittee, has been taking testimony on the state of science in the U.S. and the roles of four research agencies that are in our jurisdiction, NASA, NSF, NOAA, and NIST, in the overall science enterprise.

This morning, we turn our attention to science education, a major program within the National Science Foundation, and a component of the activities of NASA and NOAA.

The American Recovery and Reinvestment Act of 2009, the stimulus bill, which we just passed, specifically increased funding for education programs at NSF by $100 million and provided $180 million at NIST for a competitive grant program for construction of research science buildings. This illustrates the importance of science education in appropriations.

In testimony from Ralph Cicerone, President of the National Academy of Sciences, earlier this week, he pointed out that a U.S. graduate education in science and engineering is highly respected throughout the world and there are other countries working to emulate it. However, this is not the case with K through 12 science education. We all have seen reports in the press about the poor average performance of U.S. students on comparative tests of science learning.

Engineering graduate enrollment is now overwhelmingly drawn from aboard, and while this draws bright, creative minds to our shores and economy, it begs the question as to where is the stream of U.S. students to pursue graduate engineering degrees.

Our emphasis in this hearing is on K through 12 STEM education and the preparation, recruitment, and retention of science teachers.

We are pleased to have as witnesses Bill Nye, "The Science Guy." Welcome. And Mr. Harold Pratt, former President of the National Science Teachers Association. Welcome, Mr. Pratt.

Both are in touch with U.S. science education. Both are educators and through meeting with thousands of science teachers each year, they have something to bring to us.

We look forward to learning about the status of science education in the U.S. and its future direction.

Gentlemen, your written statements will be made a part of the record. We will ask you both to make your oral presentations and then the Committee will proceed with questions.

Why don't we start on the left with—I am sorry. Oh, pardon me. Congressman Wolf, who is the Ranking Member of this Subcommittee, today, now, during this Congress, was the Chairman of this Subcommittee for a number of years, did an outstanding job, has a dedicated commitment to science and science education, and has managed these accounts over the years when he was Chairman and on the Committee as well, to try to apply the scarce resources, and they were scarcer then, we hope they are more today and in the future, as best he could when he managed the Subcommittee in order to further the interest of science and education.

Mr. Wolf.

MR. WOLF OPENING STATEMENT

Mr. WOLF. Thank you, Mr. Chairman.

I really did not have anything to say, but I am going to say one thing. One, I appreciate the Chairman having these hearings. Two, I am looking forward to hearing what you are having to say.

I have some constituent things. I am going to be bopping out and back and forth. So when I do, they have already been on the schedule and I cannot change them, so do not think I am not interested.

Three, I really do worry about science. We had a report the other day. A lot of the STEM grants were laying on the table last year and were not used. And the failure—and I hope the New York Times is over this. Is a New York Times reporter here?

The New York Times has a full page story today on the fact that Barak Obama's hair is turning gray, full page, front page story. And the Chairman is having great hearings. We have had great witnesses. They have never even covered this. And full page and on the radio and TV today, it is all about Barak Obama turning gray.

I mean, do we wonder why our factories are empty and our science and we are in a period of decay on this issue? And I think the media, quite frankly, whoever is with the New York Times, you are just not doing your job. I mean, the editor of the New York

Times to cover a full, front page story and to miss the hearings that the Chairman is having and others are talking about is actually just—it is depressing.

And with that, we are looking forward to hearing your testimony.

Mr. MOLLOHAN. Mr. Nye.

MR. NYE OPENING STATEMENT

Mr. NYE. Thank you, Chairman Mollohan.

Let me say you look fantastic with the hair color that you have today.

Mr. MOLLOHAN. And it is the one the good Lord gave me and it will never change.

Mr. NYE. And I think, you know, the man can drink. That is all I am saying.

Thank you very much for having this. Very much appreciate your taking the time to listen to what I have to say.

And, as you point out, there is great concern about science education in the United States and I think it is very welcome.

General Motors came here hat in hand—oh, turn on my mike. Do you want me to start again? It is really interesting. Yeah.

General Motors came here hat in hand, U.S. based auto company. Japanese based auto companies did not come here. They did not need to because they have a different approach to designing and building cars, one that we used to be good at.

No one is surprised by this. Everybody complains about it, but the thing to do about it, the thing to change is elementary science education.

You see, something has happened where science education has been viewed as a special interest, something that is hardly different from farmers that grow a specific crop in a specific part of the country. But science is for everyone. Science involves everyone every day.

You look around in this room, everything in here owes its existence to science, whether it is the precisely made woodwork, the microphones, the paint, the understanding of chemistry, the lighting, the electricity. This all comes from science.

So right now we have a problem. Every year I meet not dozens, not hundreds, not thousands, I meet tens of thousands of science teachers every year. I have yet to meet one, I have not met one science teacher who believes in No Child Left Behind. So I do not know what it is exactly, but there is something wrong. Something is wrong with No Child Left Behind and it is not in anyone's interest to not fix it.

The thing that has happened is science teachers have to be held accountable in exhausting ways. They have to administer tests. They have to do assessments. They have to file reports for officials. And they cannot do the one thing, the one thing that made me go into science, and certainly my science teachers, they do not have time right now to inspire. That is the key.

You see, science starts with observation and then it goes through something we often call the scientific method and so on. But it starts with an interest, with being inspired. And so we have to change this. We have to make it easier for science teachers to do their job.

And generally I would say the solution, if there is one solution, we have to do everything all at once. If you ask science teachers who have children who do not have a tradition of academic rigor, who do not have strong family that believes in education, I would say what we have to do is fix the parents. Well, that is not possible. We will not be able to fix the parents. We have to fix everything else that we can.

So we have to make it so that someone graduating from, let us say, engineering school, instead of choosing to go to work for a very good software company might instead choose to become a science teacher. In order to do that, you have to pay people. You have to pay the educators. And we have to have a situation where there are not 30 children in a class or 50. We have to have closer to 15 or 16 kids in a class.

And I admit we have to cut the dead wood. There are certain teachers that are not holding up their end of the bargain. And I know we have to negotiate with teaching unions and so on, but that has also got to be done.

And then I believe strongly in national standards. And I will just tell you right now national standards have to include evolution. The underlying idea in all of geology, the fundamental idea, the big discovery in all of geology is plate tectonics. Plate tectonics is a great idea. It is fantastic. It changed the world.

But the underlying idea in all of life science is evolution. Evolution binds everything together like nothing else. So we have to just reach agreement on that and move on. If you want to study things that are not evolution, just do it outside of science class.

So in a few hours, NASA will launch the Kepler Mission which will look for terrestrial planets. These will be planets that are like the earth on other stars. These are places that my grandparents, these are very recent ancestors, even my grandparents could not imagine such places.

And we are doing that not with an individual as Kepler was but with a society who believes in this, believes in spending its treasure on making discoveries about our place in the universe. Where did we come from? The oldest of human questions. And these are science questions.

Now, as you know, I am the Vice President of the Planetary Society, a society started by Carl Sagan and a couple of his colleagues. And I am a big believer in planetary citizenship, that we are all together on this one world.

But I was also born in the United States and I am a patriot. My father fought on Wake Island and spent 44 months in prison camp. My mother was a Lieutenant in the Navy and was a cryptographer. She worked on breaking the enemy's Enigma code.

So this patriotism may come from the household I grew up in, but for my part, I want the next generation of biofuels, the next generation of high performance batteries, the next generation of flood and volcano monitoring systems, the next smart pasture farming operations, I want all of those things to be created here in the United States by our citizens so that we can lead the world and improve the quality of life for everyone everywhere on planet earth.

Now, if we do not support science education, I claim that you or we will be the first generation ever in the United States history to leave the world worse than we found it. We will leave the world, the quality of life for our kids and grandkids lower than our quality of life.

So I thank you for all you have done in the last few weeks to support science education and I thank you for listening, but we need to do a great deal more and we need to do it as soon as we can for the betterment of all human kind.

Thank you very much.

[Written testimony by Mr. Bill Nye follows:]

Bill Nye's Testimony for the Commerce, Justice, & Science Appropriations Committee

Ladies & Gentlemen, distinguished guests, and colleagues: There is generally great concern about science education in the United States. Any consumer shopping today knows that the products, even the food, that she or he buys is produced elsewhere- overseas or over-borders. General Motors comes to you hat in hand- not Toyota. Is anyone here surprised? For many, science seems like another special interest group, out of the main stream. But notice, everything in the this room, the tables, the chairs, the electronics, even the plants came to be here, because their designers understood math and science.

As a popular science educator, I have met tens of thousands of science teachers. I have not yet met one, who feels good about No Child Left Behind. Despite the best of intentions, our science teachers are burdened with extra tests, assessments, and reports. Right now, they cannot do their most important work: inspiration- inspiring the next generation of scientists and engineers with passion and purpose.

Tonight, the National Aeronautics and Space Administration will launch the Kepler telescope mission to observe extrasolar planets- worlds beyond ours, places even ancestors as recent as our grandparents could hardly imagine. As the Vice President of the Planetary Society, the world's largest space interest organization, I promote the idea that we are all citizens of Earth.

But, I am also a citizen of the United States. In World War II, my father defended Wake Island. My mother worked on the enemy's Enigma code. I am a patriot. I would prefer that the next generation of high-speed trains be designed and built here. I would prefer that the next generation of solar panels, of biofuels, of high performance batteries, of flood and volcano monitoring systems, and of smart pasture farms be created, built, and established here- in the U.S. I would prefer that United States helped people everywhere, leading the way with new technologies and discoveries. I imagine all of you would, too.

The alternative is grim. Without the world's best science, for the first time in U.S. history, the next generation, your children and your grandchildren, would have a substantially lower quality of life than you did. That is not our way. Science educators must be given the resources to excel. If a bright future led by the United States is what we all want, we must embrace, promote, and provide money for science education. Fund the future of science. Let's change the world.

Bill Nye
5 March 2009

Mr. MOLLOHAN. Thank you, Mr. Nye.
Mr. Pratt.

MR. PRATT OPENING STATEMENT

Mr. PRATT. Thank you. Chairman Mollohan, Ranking Member Wolf, and distinguished members of the Subcommittee, my name is Harold Pratt and I am testifying today on behalf of the National Science Teachers Association.

I have been a very active science educator for 53 years and you will notice my hair has some of the same color that we revere so much. I am still active as a consultant and an author to this day and appreciate the opportunity to provide testimony about the state of science education in the United States.

I would also like to thank this Committee and Congress for the increased funding for science and science education in the stimulus bill and the recent Omnibus bill in federal year 2009.

It is important that Congress continues to fund "America Competes," especially funding for the Education and Human Resources Directorate at the National Science Foundation so we can address many of the challenges that Bill and you are very aware of.

Much of the science education research conducted over the past few years largely with NSF funding has been promising and productive. NSF-sponsored research on student learning summarized recently by the National Research Council tells us young children are capable of learning far more complex and abstract ideas than we previously realized.

This and other NSF research has the potential to revolutionize the way we teach science and the way it is learned in our schools.

Unfortunately, very little of this research finds its way into the majority of classrooms where it can have an impact on science learning. We have to do a much better job of disseminating and actively implementing the research findings in our classrooms so that it can be used to increase science achievement.

A second challenge is the quantity and quality of science provided at the elementary level. Many people, many adults in this world do not realize that increasing the number of science and math graduates, which I know is one of the goals of this group and others, relies a great deal on the science we provide to our youngest learners.

Unfortunately, many elementary schools have reduced the amount of science education their students are receiving or have even eliminated it altogether because of the pressure to show achievement in other subjects. Many elementary teachers are also ill prepared to teach science at this level.

A third challenge is the lack of professional development provided to science educators. All teachers of science at all levels must have access to long-term, coherent, professional development so they know the science they are teaching, they understand how students learn science, and they can plan and deliver the quality science instruction.

Unfortunately, again, many districts have been forced to cut back on providing funding for science teacher training. We hope that Congress can encourage school administrators and the federal agencies to invest more in the professional development of teachers.

Science teacher education is also a concern. Last year, the National Science Board called for a review of teacher education programs and how well they provide science and the training in the subject that prospective teachers will teach.

Improving science standards and assessments that Bill mentioned is another key issue at the state level and we look forward to the President's agenda in this area.

Research from what we call the trends in mathematic and science studies, sometimes called TIMSS, and the NRC tell us the current state of science standards contains far too many topics, provide too much variation from state to state, and does not tell us what students need to learn.

No discussion of quality science education would be complete without mentioning a high school science laboratory experience. Unfortunately, the news in this area is not good.

In 2005, the NRC found that most students had a poor experience in the science laboratory. Teachers were not prepared to run lab activities. State exams did not effectively measure laboratory skills and the quality of laboratory equipment was widely diverse. Funding for "The America Competes Act," including full funding of the Partnerships for Access to Laboratory Science Provisions, will help address this problem.

Finally, as many of you probably have heard from your constituents, many, if not most, school districts are finding it hard to recruit and retain science teachers. Many schools have to compete with business and industry for high school science teachers. Research tells us that the teacher shortage in science education may be due in part to early exits because of the poor teaching conditions that exist in schools and the lack of administrative support.

Mr. Chairman, although many of these key challenges need to be addressed at the local and state level, at the federal level, we would like to see additional resources for the National Science Foundation so the agency can continue to expand upon its research and development efforts in science and math education.

As pointed out in recent reports a couple years ago, federal STEM programs at the federal agencies, including the agencies under the jurisdiction of this Subcommittee and the Department of Education, Department of Energy and Department of Defense, need to be better coordinated and focused in a systematic manner that first truly identifies the needs of teachers, schools, and districts so that federal dollars can be used to best address these needs.

Like the science content standards in many states and the words that we have heard often repeated, the sum total of these federal programs are what I would describe as a mile wide and an inch deep. A collaborative effort to streamline and coordinate federal STEM programs can best be done by OSTP and will go a long way to address many of the challenges I have presented here today.

Thank you. And I thank you for the opportunity to testify and I look forward and welcome your questions.

[Written statement by Harold Pratt, Former President, National Science Teachers Association follows:]

Testimony of
Harold Pratt
Former President, National Science Teachers Association

Before the
House Committee on Appropriations Subcommittee on Commerce, Justice and Science
U.S. House of Representatives 2359 Rayburn
March 5, 2009

Chairman Mollohan, Ranking Member Wolf, and distinguished members of the Subcommittee, my name is Harold Pratt and today I am presenting testimony on behalf of the National Science Teachers Association (NSTA). I have been actively involved in science education for 53 years as a classroom teacher, as a district science supervisor, and as a curriculum developer. At the national level I was a staff member at the Center for Science, Mathematics, and Engineering Education at the National Research Council (NRC) and I was a Senior Program Officer for the NRC when that group and others developed the National Science Education Standards in the mid-1990s. I was president of NSTA in 2001-2002 and continue to actively work as a consultant and author.

Thank you for this opportunity to provide testimony about the state of science education in the United States. To begin I would like to start with some positive trends we are seeing in science education before I outline many of the challenges we face.

First and foremost, we would like to thank this committee and the Congress for the increased funding for the science agencies in the ARRA and recent omnibus for FY2009. While these increases are very good for science and the science education initiatives at the agencies, it is important that Congress continues work to fully fund the AMERICA COMPETES Act.

Second, science educators nationwide are thrilled with President Obama's pledge to make math and science education a national priority and his promise to improve science assessments; to help math and science students with college aid; and to increase the number of science and math graduates.

Another bright spot is the science education research conducted over the past few years, largely with funding from the National Science Foundation, in the areas of student learning.

One example of this promising research is the NSF-sponsored study reported in the NRC publication *Taking Science To School, Learning and Teaching Science in Grades K-8*. This research tells us young children are capable of learning far more complex and abstract ideas than we had previously realized and how students learn science concepts over time. Thanks to this research, we know that children can learn complex science ideas by actively engaging in science investigations; by working with peers; by using specialized ways of talking and writing; and by doing mechanical, mathematical and computer-based modeling.

Mr. Chairman we believe that this research, as well as other types of research focusing on knowledge and cognitive development from the NSF and other agencies, has the potential to revolutionize the way science is taught and learned. Unfortunately, very little of this research finds its way into the majority of classrooms where it can have an impact.

Linking research to practice is one of the leading challenges in science education today. The problem is two fold. First, we simply must find better ways to link the community of science education researchers, including those in the federal agencies, with one another and with schools. Second, we must effectively disseminate and actively implement the vast research findings that can and will have an impact on our schools and classroom teachers. Last fall the STEM Education Coalition urged the National Science Foundation and Congress to provide more funding for the dissemination and implementation of current NSF education research and products. Critical research in science education must be implemented in our classrooms nationwide and used in a manner leading to increased student achievement in the sciences.

In addition to providing more schools and teachers with critical research on student learning and other issues, as a nation **we must improve the quality and quantity of the science provided at the elementary level.** Increasing the number of science and math graduates relies more on our success at the elementary level than many people realize. Many district and school administrators are not placing enough focus on the quality and the amount of science education that is provided to our young students. In fact many elementary schools have reduced the amount of science education their students are receiving or have eliminated it altogether because of pressure to show achievement in other subjects. Last year The Center on Education Policy, a respected think tank that monitors No Child Left Behind, examined the amount of time spent during the school week on core academic subjects. The CEP found that since NCLB became law a majority of districts cut time on science instruction at the elementary level by at least 75 minutes per week in science.

The NSF-funded study National Survey of Science and Math Education also shows that elementary school science teachers are lacking in content preparation, especially in the physical sciences. 75 percent of the elementary teachers in the survey reported they felt well qualified to teach language arts and reading, and 60 percent said they felt qualified to teach mathematics, but only about 25 percent reported they felt well qualified to teach science. Our youngest students deserve better, especially at a time when science instruction is critical to laying the foundation for their future learning and critical thinking skills and their decisions to pursue a future in STEM.

Another area of concern is the **quantity and quality of professional development provided to elementary teachers and all teachers of science.** Long-term, coherent, reform-based professional development is essential. All teachers of science must have a sufficient knowledge of science, knowledge of how students learn science, and knowledge of how to plan effective instruction. Ongoing quality professional development should be coherent with other activities and focus on content knowledge and active learning. [1] While it commonplace for most businesses to invest funding in staff training, very few budgeted dollars go to teacher professional development.

In an NSTA survey conducted earlier this month of more than 3,400 teachers, 58 percent said they did not have enough professional development opportunities in science. 67 percent reported they experienced less than 5 hours a month of professional development during the school year (a total of approximately 50 hours during the school year). Research tells us that it takes at least 80 hours of professional development to bring about meaningful change in teaching behaviors.[2]

The preparation of science educators is another issue facing the science education community. In its *National Action Plan for Addressing the Critical Needs of the U.S. Science, Technology, Engineering, and Mathematics Education System*, the National Science Board called for a review of teacher education programs and how well prospective teachers are grounded in academic content in the subjects they will teach. The NSB encourages higher education leaders to strengthen K–8 teacher education programs so that they provide a deeper understanding of the content knowledge necessary to teach mathematics and science.

NSF and others must also work to change university culture in fundamental ways to bridge the cultural divide between the schools of arts and science and schools of education and their efforts to encourage and retain more students in STEM fields. More collaboration between these communities would lead to stronger teacher preparation programs in science and mathematics. This area of focus for NSF would go a long way in improving the 'system' of education.

Improving science standards and assessments is another key issue in science education and we look forward to the President's agenda in this area. Research from the Trends in International Math and Science Study (TIMSS) tells us that current state science standards contain far too many topics to teach. In fact our recent survey indicates that teachers want to know how to teach fewer topics in-depth. Efforts to clarify the key concepts of the current standards in science, which can then be coordinated with curriculum, assessments, and teacher professional development, are essential. NSTA is currently working with Achieve, the National Academies, and AAAS on an initiative to

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[1] Garet, M.S., Porter, A., Desimone, L., Birman, B., & Yoon, K. (2001). What makes professional development effective? Results from a national sample of teachers. *American Educational Research Journal,* 38(4), 915-945.

[2] Supovitz, J., & Turner, H. (2000). The effects of professional development on science teacher practices and classroom culture. *Journal of Research on Science Teaching*, 37(9), 963-980.

clarify science standards and identify core science concepts that will provide much needed guidance to our schools and classroom teachers.

No discussion of quality science education would be complete without mentioning the high school laboratory experience. Unfortunately the news in this area continues to be bad. In 2005 the NRC report *America's Lab Report Investigations in High School Science* found that **most students had a poor experience in the science laboratory.** The report found that teachers were not prepared to run labs, state exams did not effectively measure lab skills, the quality of lab equipment was widely diverse, and that the very definition of what constitutes a "laboratory" experience is still being debated in far too many schools. For an experience that is vital in science more could be done to delineate the guidelines for science laboratories, connect laboratories to the science of today, provide better training for high school teachers, and emphasize labs in the middle grades.

Finally, many school districts are finding it hard to **recruit, retain and support teachers of science.** As pointed out in the report *An American Imperative* from the Business Higher Education Forum, the United States will need almost 280,000 science and math teachers in the next few years.

Teacher retention is a major concern because it is unlikely the current system can quickly produce the needed numbers of science teachers. The teacher is the single most important factor in the education equation. Good teachers must be supported and encouraged to remain in the teaching profession. The National Commission on Teaching and America's Future reported in 2003 that approximately a third of America's new teachers leave teaching sometime during their first three years of teaching; almost half leave during the first five years. Research from NSF and from NSTA tell us that the "teacher shortage" in science education may be due to early exits because of conditions of schooling such as lack of administrative support and student motivation.

Teacher compensation is also an issue. The average beginning teacher salary in the 2004–2005 school year was $31,753 [3] while the average salary for recent science and engineering bachelor's degree recipients in 2003 was $40,900.[4] The national average salary for public teachers in 2005–06 was $49,026[5] while the median annual earnings (regardless of education) in S&E occupations were $67,780.[6]

Obviously science educators with degrees in science fields have many other lucrative career options. The competition for teachers is quite extensive. While we applaud the NSF Noyce Scholarship program and other initiatives to get STEM majors into the field, frankly we are not doing everything we can to attract our best and brightest into teaching.

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[3] The American Federation of Teachers' (AFT) *Survey and Analysis of Teacher Salary Trends 2005, p. 9*

[4] NSB, *Science and Engineering Indicators 2008* (NSB-08-1) (http://www.nsf.gov/statistics/seind08/),

[5] Rankings & Estimates: Rankings of the States 2006 and Estimates of School Statistics 2007, National Education Association, December 2007)

[6] NSB, *Science and Engineering Indicators 2008* (NSB-08-1) (http://www.nsf.gov/statistics/seind08/),

Mr. Chairman, I have presented what we believe are some of the key challenges to science education today:

- Linking research to classroom practice
- Improving elementary science education
- Improving the quantity and quality of professional development provided to teachers of science, including elementary teachers
- Better preparation of science educators
- Improving science standards and assessments
- Improving the quality of high school laboratory experiences; and
- Attracting, retaining and supporting teachers of science.

As I mentioned earlier, we applaud the funding this committee has provided to many of STEM education programs at the agencies under the jurisdiction of this committee. K-12 education programs at NASA have sought to attract and retain students in STEM disciplines with educational opportunities for students, teachers and faculty.

NOAA Environmental Literacy Grants have made it possible to deliver educational materials to thousands of teachers and students.

We are especially pleased with the increased funding for NSF's Education and Human Resources Directorate (EHR) in both the stimulus bill and the Omnibus legislation. Programs under the NSF EHR Directorate have provided STEM education with new ideas, new technologies, new curriculum, new resources and materials, and new talent from which new ideas will continue to flow. This is vital to our knowledge base in STEM education, and to our continued economic prosperity, national security, and workforce preparation.

NSTA would like to see **additional resources to the NSF so the agency can continue and expand upon its research and development efforts in science and math education.** This funding should include a greater emphasis on the dissemination and implementation of research more broadly into the classroom environments. We talk about pockets of excellence here and there, largely funded with NSF dollars, but very little of the research generated from these initiatives reaches the majority of classrooms or results in a substantial increase in student achievement or more students pursuing science. Additional funding would allow the NSF to explore innovations in all domains of science education and it would support programs at the proper scale to ensure an impact on science learning.

Second, as the Report of the Academic Competitiveness Council and the Government Accounting Office report (GAO-06-114*) Higher Education: Federal Science, Technology, Engineering, and Mathematics Programs and Related Trends* have pointed out, **federal STEM programs at the federal agencies, including the agencies under the jurisdiction of this committee and the Department of Education, Department of Energy, and the DoD, need to be better coordinated in a systemic manner that first truly identifies the needs of teachers, schools, and districts so that federal dollars can be used to best address these needs.**

NSTA supports a provision in H.R. 6104, Enhancing Science, Technology, Engineering, and Mathematics Education Act of 2008, introduced in the last Congress by Representative Honda, that calls for the **Office of Science and Technology Policy to create a standing committee on STEM Education within the National Science and Technology Council with the responsibility of coordinating and focusing all Federal STEM education programs so they meet the primary needs of teachers and schools.**

Third, **Congress can encourage decision makers in schools to invest more in a long-term commitment to teacher professional development.** Federal research aimed at teacher professional development and increased funding for professional development will help state and local school districts provide science-specific professional development to both pre-service and in-service teachers. We need to help end the isolation that many classroom science teachers feel by providing more time for structured professional development training; collaboration among teachers; study groups, and lesson study.

In addition, elementary teachers need opportunities to deepen their knowledge of the science content of the K-8 curriculum. One of the most significant recommendations the NRC makes in *Taking Science To School* is "Federal Agencies that support professional development should require that the programs they fund incorporate the four strands of science proficiency, focus on core ideas in science and enhance teachers' science content knowledge, knowledge of how students learn science, and knowledge of how to teach science."

Finally, we urge Congress to provide funding for the America Competes Act, including the Partnerships for Access to Laboratory Science provision (Section 4015 of the America COMPETES Act) that would create a pilot program at NSF to study laboratories in science, which could include studies into helping teachers implement laboratories, the design and sequencing of laboratories, and essential aspects of effective laboratory instruction.

Mr. Chairman and members of the committee, elementary to college science educators are very encouraged by the Administration's strong commitment to science and math education. Exciting new research currently underway can have a huge impact on the teaching and learning of science, but only if it is properly funded and implemented in the classroom. We thank you for stronger funding for science education, and believe a coordinated effort to focus all Federal STEM education programs so they better meet the primary needs of teachers and schools is necessary and will also go a long way to address many of the challenges I have outlined here today. I thank you for this chance to testify here today and look forward to answering any questions you may have.

Mr. Mollohan Questions

Mr. MOLLOHAN. Well, thank both the witnesses for their excellent testimony.

SCIENCE EDUCATION

Both of you, in your respective ways, made the point that we had to approach this comprehensively and in a coordinated way.

Mr. Nye made the statement right up front that they have to do everything all at once. And Mr. Pratt gave us a detailed listing of that and it might not have been totally inclusive, but it certainly was comprehensive.

I would like to give each of you an opportunity just to elaborate on that notion we have to do everything all at once. I certainly agree with that. I think you have to do it from soup to nuts, from education, the science education, which is a college function obviously, and import it into the elementary schools, K through 12 and bring it forward.

But I would like to hear you all talk, each in turn, talk about that notion.

Mr. NYE. Let me say that you if you are going to get a kid, a student to have lifelong passion for science, it is generally agreed you have to get that passion before you are ten, before you are ten years old.

Now, you can get in debates about maybe it is 11, maybe it is—I do not think it as late as 12, but there is no one—very few people would argue that you can get somebody to have a lifelong passion for almost anything by the time he or she is 17 or 18.

So this feature of the human brain or whatever that we get this passion when we are very young, we need to exploit or enhance or take advantage of. And this is the point that Mr. Pratt was making, that we have to really emphasize elementary science education.

And this involves, the expression that everybody loves is hands on and it means if you—the old saying is if you want a kid to learn about magnetism, you have to just give the kid magnets and he or she will figure it out.

But if schools do not have the resources for that, then where do they turn? Well, it has been shown to my satisfaction that about half of what you learn about science is learned what is called informally. And informal is the technical term that means outside of the classroom.

But then what is outside of the classroom? Outside of the classroom might be something like the after school program. And in my opinion, the most effective informal education settings are where the person, the instructor, the educator, the person running the after school program is passionate. Wherever that person is enthusiastic about science, the thing is successful.

And so as I tell teachers all the time, you should want to teach science because you have got props. You have got things that blow up. What is more fun than that?

And so we have a situation, and then I am going to hand it over to you, Harold, in just a moment, is we have a situation where people who were not raised with scientific traditions are asked to teach elementary science and they are uncomfortable with it.

But in my view, this is a great chance for teacher development because almost anyone who goes into elementary teaching is passionate, wants to influence young people.

And so if we give them the tools to teach science, they will do an excellent job. But right now those tools are not very well distributed.

Mr. PRATT. We do have to think comprehensively and I would add systemically. And let me explain what that means. We have to think about the system from A to Z.

But first let me start with a negative just to set the stage in a way good teachers would not usually do. It is not simply developing high standards and rigorous assessments and then invoking penalties when the success is not met. And I think that may represent much of a model that is in the minds of both politicians and educators across this country today.

So let me fill in the space or the gap between the standards and the assessment because that is where the work lies and that is where the support and the funding needs to be made, not to decrease the importance of strong standards and quality assessments, but to fill the gap, what I am going to call the gap between those.

And, of course, it starts with teachers at university education. It is the model for teaching and learning that unfortunately gets replicated at K–12 by some very poor but improving, I must say, standards and examples of teaching at the university level.

Mr. MOLLOHAN. Will you say that again, please?

Mr. PRATT. Yes. What happens is that teachers, particularly at the secondary level, but maybe to some degree at all levels, teach the way they are taught. So whether we like it or not, university teaching, and you know the worst case scenario are those huge freshman classes, you know, arenas of 350 students and a microphone with a professor standing behind it.

Now, there are improvements and NSF is making efforts and there are some very good examples across the country where there is an attempt and you have heard from some Nobel Prize winners such as Eric Misor at Harvard and so on who have testified and written extensively about this, but unfortunately the number of those is fairly small.

So what the classroom teacher faces then is very little teaching experience or modeling and they need the professional development immediately. Young teachers do not survive for a whole variety of reasons.

Part of it is the lack of training. Part of it is the lack of support. Part of it is the poor teaching assignments they are given their first years because they are low on the totem pole, so to speak, on the seniority in the school district. They have poor instructional materials. In other words, they have materials that really do not help them understand what we call inquiry based teaching or teaching beyond the facts. They do not have the professional development support that they need. They often do not have an administrator who understands what quality science teaching is.

So they hit a scene at the local school level where at least half of them drop out in the first three to five years simply because of a variety of reasons that just seem to pile up on them.

So we need quality instructional materials. We need the professional development in the use of those materials. We need the support in terms of physical materials to teach with as well as the laboratories and facilities at all levels. We think of laboratories at the high school level. We do not have laboratories at the elementary level, but we need facilities that are inducive or conducive to teaching elementary science.

And then, of course, we do need the support from the community. We need a standing for teachers that is well recognized and revered, if you will, at the local level. And we need time for them to teach elementary science.

Then we need quality assessments that are consistent with those standards and the type of instruction, the goals of instruction. So we need research and development and the development of assessments that are consistent with what we know to be quality science and that the NSF research tells us is very productive and very successful.

Mr. MOLLOHAN. Thank you, gentlemen.

Mr. Aderholt.

MR. ADERHOLT QUESTIONS

Mr. ADERHOLT. Thank you, Mr. Chairman. It is good to have our guests here today.

Thank you both for being here.

I would concur with you, Dr. Nye, that the Chairman and Ranking Member's gray hair does look very nice——

Mr. NYE. It is fabulous.

Mr. ADERHOLT [continuing]. And distinguished on them. I never mind my hair turning gray. It is the turning loose part that has always been a concern to me.

So, anyway, it is good to have you here and thank you for taking time to come before our Subcommittee and to share your insight and your thoughts on science, an issue that is very important in this day and age.

NO CHILD LEFT BEHIND

One of the things that you mentioned about the No Child Left Behind Act, and I think probably most everybody on this dais up here probably was here during that time, and I am not sure every one of us supported it, but we were here when that legislation came before us.

Mr. NYE. It seemed like a good idea.

Mr. ADERHOLT. Certainly there are few federal programs that are perfect. Matter of fact, any time that you have a government program that is so big and so vast as No Child Left Behind, it is going to be riddled with a lot of problems. And so I do not think anyone would disagree with that.

I guess what I would be asking you, and this is just an honest question, you mentioned the fact that teachers have a lot of paperwork to do. What other ways do you think that we would need to revise No Child Left Behind or some goals that we need to look at when we do change, and we will be changing No Child Left Behind and making changes to it over the next several months? You know, what would you offer?

Mr. NYE. Fewer standards and, if you will, more succinct standards that are achievable. And then you want standards that are achievable through hands-on education rather—this is the old question for any academic setting, lecture versus laboratory. This is an old saying.

How much laboratory should you have versus lecture? And this is a good question in the college level, university level. But in elementary school, they really do not need any lecture. What you need is hands-on time when it comes to science education.

And so from my understanding, there are many schools where science is not assessed at the elementary level, where it is not part of the standards. And this is especially true of astronomy. May I remind you 2009 is the year of astronomy.

We are the first, the people living now are the first set of humans to realize that we live on a planet that is hardly different from many, many other planets and they are going to live through a time when earth-like planets are discovered elsewhere.

And I mention this only because this is something that you should be aware of certainly before you are 12 years old, but right now we do not have a national standard in that one example. We do not have a national standard for that. And we could change that. That would be something, for example, we could change.

And there are people that are expert on this. And what happens, it is my understanding, everybody wants his or her piece of the pie and, I mean, this is your business is compromise. But what we need is to let science be regarded as important at the elementary level. And I think that would be a fundamental change in No Child Left Behind from what I understand.

Mr. ADERHOLT. Thank you.

Of course, the President has repeatedly asserted that, as leaders and members on both sides of the aisle will attest up here in Washington, that no child's education can be fully maximized without significant involvement from the parents.

And I am a parent of a five-year-old and a nine-year-old. And what would be your suggestions as far as fostering and furthering the science education outside the classroom when they are home, of course, other than watching episodes of Bill Nye, "The Science Guy"?

PARENTS AND SCIENCE

Mr. NYE. Well, that is fabulous. You are looking for a specific thing for you as a parent?

Mr. ADERHOLT. Yeah. Just what would you——

Mr. NYE. Let them mess around in the kitchen. And then as part of that, they have to clean it up. That has got to be part of the bargain.

And so you can do things. One of the tenets, I am reluctant to say innovations, on "The Science Guy" show is we divided science into physical science, chemistry and physics, life science, which would be general biology, and then things about the human body, and then what I like to call planetary science, which is earth science and astronomy.

And I claim if you just try to nudge kids into those three categories every month, you will have fun. And people will inherently learn science. Take food coloring and try to make it in the shape of a squid. That is not so easy, but squid do it with their ink every day or whenever they need to. I do not interview that many squid. I have spoken to them, but I have never really had a response.

Then with regard to planetary science, you know, you can look at the moon all the time. And we strongly encourage you to make diagrams of the phases of the moon with a piece of soap scrape because you can—then the window gets cleaned at the end of the month too.

And so I just encourage you to allow investigation, to let people, let kids make a mess and clean it up because you learn things about the—well, water is very important and you learn things about the nature of materials, like paper is different from plastic, metal is different from paper. You learn things about the world that if you are going to go on to be a scientist or engineer or if you are going to go on to be a legislator, you want everybody to be scientifically literate in this fundamental way, have respect for science.

So I say let them mess around. That is a great question.

Mr. ADERHOLT. Just briefly, in your opening comments, you mentioned the part about evolution and the importance of teaching evolution.

Talk a little about that from your perspective and just expand a little bit about——

EVOLUTION

Mr. NYE. Well, I get journals and reports about all the many lawsuits in the United States associated with people trying to ban or modify, ban evolution in science class or modify science to include things that were described by the judge in Dover, Pennsylvania as breathtaking inanity. This would be the notion that there is some scheme of thought that would be associated with a reasoning person believing the earth is, for example, 6,000 earth years old. To me, that makes your life really complicated.

Where I went to school in New York State, you walk around and they are Silurian fossils. There are trilobites everywhere on the ground. You cannot miss them.

So then to try to—this is only for example—to try to explain away the existence of a Silurian fossil through this complex non-physical science completely outside of every-day experience to me seems just fantastically complicated and makes, in my experience, makes children very uncomfortable because the world becomes bewildering.

Instead, if you want to study philosophy, and certainly some of the best ideas humans have ever had are in the Bible, I mean, I am right there with you, but this understanding of the notion of deep time and the fundamental reason we are so much more alike than we are different and the idea that humans all came from Africa and we migrated across the world and the reason we eat wheat and the reason some people have very light brown skin and other people have somewhat darker brown skin is all explained by this fundamental idea of evolution.

If you try to leave that out, your worlds become so amazingly complicated when you are ten years old. It just is nonsensical.

To go to some place like the Grand Canyon and look at layer after layer after layer and try to make sense of that, to look at the what is generally called the ring of fire, we have volcanos in Hawaii that were created one way, we have volcanos in Washington State, Oregon, northern California created in another way, and to try to make sense of that and the age of rocks and the radiation, the radioactive isotopes that lead us to make these inferences about the age of the world, to try to do all that using something other than science is just fantastically complicated. And I do not think it is good for a kid.

And so, as I say, if you want to study philosophy and alternative ways or what Karl Sagen, my old professor, referred to as creation myths, that is a worthy study, but it is not what we have learned through the process of science.

So wasting national resources debating an alternative to evolution, I think, is squandering our treasure.

Mr. ADERHOLT. Do you have some of your colleagues that would disagree with that or, you know, some of your respected colleagues?

Mr. NYE. Scientists?

Mr. ADERHOLT. Yes.

Mr. NYE. I never met one. Now, I have debated people who call themselves intelligent designers or believe intelligent design. And I have been completely unimpressed or how to say, I have been astonished at how they are willing to ignore everything they can touch and see.

See, here is the problem. Here is what is out of our every-day experience. When we look at a device like this remarkable phone, we know that it was designed by people. Everything in this room, everything, even— are there are some plants here— everything came out of somebody's head. Every shape, every color, everything was conceived by a person.

So when we see remarkable systems that fit together like, say, in a forest where there are birds that live in this part of the tree, there are other animals that live in this part of the tree, the whole thing depends on these microbes that work in the soil, and the system seems to fit together perfectly, these people on, if I may, the other side assume or presume that there must be a designer associated with that.

And at first, that seems reasonable, but that is not how evolution works. And these discoveries were made in the 18—they might have been made long before that, but they were certainly documented in the 19th century. And so that is not how evolution works. Evolution works the other way. It is the bottom up.

So, as we say, the bad designs are eaten by the good ones. And so if you live at any moment in history, it looks like it all fits together because if it did not, it had disappeared. This is quite an insight. It is remarkable.

If you go to Dinosaur National Monument set aside in the Wilson Administration, that is some time ago, it is astonishing. There are more species there. There are species discovered every year. In this place that is century old, guys, people are out there digging every day. It is amazing.

And so you can, as I always say, you can feel insignificant as this insignificant traveler in this time that is only going in one direction and you can feel that your thoughts and your actions make no difference at all.

But then on the other hand, using our mind and the process of science, we can understand all that. And that is worthy of respect. That is a remarkable thing that humans who are hardly different from many other species extant today can figure all this out. That is worthy of something. That is worthy of celebrating. That is science.

Mr. ADERHOLT. Thank you.

Mr. MOLLOHAN. Thank you, Mr. Aderholt.

Mr. Serrano.

MR. SERRANO QUESTIONS

Mr. SERRANO. Thank you, Mr. Chairman.

I am tempted to ask you a profound question, but I am also tempted to ask you, Mr. Nye, some basic questions, like why isn't my Blackberry working in this room.

Mr. NYE. Could be the man.

Mr. SERRANO. Where do you keep your Emmys?

Mr. NYE. I keep two of them on the mantlepiece and I keep five of them in a box.

Mr. SERRANO. And I have to——

Mr. NYE. That is quite a thing. Thank you. That was a remarkable time. Thank you.

Mr. SERRANO. And we have a running gag in this Committee as to how long it takes me to bring up Cuba and Puerto Rico, so why isn't the little frog, the coqui, seen anywhere else but in Puerto Rico? And it made its way to Hawaii recently and the Hawaiians are complaining that it is a nuisance. For the first time, it sang somewhere outside of Puerto Rico and, yet, Puerto Ricans see it as the musical soundtrack to their lives on the island and for the first time, it made it there. And no scientist has been able to tell us why it only sings in Puerto Rico.

Mr. NYE. Well, wouldn't that be worth knowing?

Mr. SERRANO. Yes.

Mr. NYE. Wouldn't that be a fascinating thing to——

Mr. SERRANO. And that is why it leads me to my next question, to the real question now that I let the audience know you won a bunch of Emmys and——

Mr. NYE. That is very nice. Thank you.

Mr. SERRANO. And you blame me for the problems with the Blackberry.

Mr. NYE. Well, these devices are made by people and people make mistakes.

MINORITY AND SCIENCE TEACHERS

Mr. SERRANO. All I was trying to find out if Japan beat China in that game in the World Classic and I think they did.

Seriously, we are honored to have both of you before the Committee. And as one of the few members of Congress who was a school professional, a teacher's aide, and after that a school administrator, a program administrator, I know exactly what you are talking about in terms of the lack of support that young science teachers get and the lack of importance placed on that part of the profession.

Mr. NYE. Well, another job where everybody quit within five years, not to go, if I may, to another law firm to continue being, for example, a lawyer, but to go into a completely different profession, I mean, that is not a good thing.

Mr. SERRANO. That used to be the life span of a member of Congress, about three to five years in Congress.

But I must tell you something you do not know. And that is as both of you were talking about the profession, there are a lot of young people here today and they were all nodding their heads. Now, they are the recipients of what those teachers have to offer. And when you were talking about the issues that teachers face, they were all agreeing with you, which brings me to a question.

You know, African Americans now represent about 12 percent of the population and Hispanics represent about 15 percent, yet both of them are getting about 8.7, 8 percent respectively degrees in science and engineering fields.

In addition to that, we have community colleges that have students participating in STEM programs or science, technology, engineering, and mathematics, which could help young people move on to a four year degree.

So while you have been speaking in general terms and that is the best way to approach a lot of these things, my question is, is there something we could be doing to encourage certain segments of the society to move into these fields of study?

Mr. NYE. Well, how much of that, what I would want to know is how much of that is associated with the wealth of the school district. You see, the PB&J, the passion, beauty, and joy of science is that whatever we discover in science is true for everyone.

And I have, if I may, been preaching this for a long time, that if—the expression that was very popular ten or twelve years ago was at risk kids—if at risk kids are exposed to science, they can go into careers where their work is evaluated objectively.

And so just like everything else that has to do with, if I may, African Americans and Hispanics, people of non-European descent, it takes time, that the traditions that go back, I guess, about four centuries are taking time to wipe out. But I am thrilled right now. I think everything is going to change. I think it is going to be a wonderful future.

And so I say to at risk kids or kids from school districts that are not as wealthy pursue science because your work is objectively evaluated and you can excel. And you will almost certainly get a job that you love to come to every day, just like you.

Mr. SERRANO. And we do.

Mr. Pratt.

ELEMENTARY SCIENCE

Mr. PRATT. Elementary science is where I would start because you can get closer to the family and you can get closer to the home through elementary science.

And just to pick a specific point and it is related not just to students of minority or unrepresented students, it goes for all students, is that when language development takes precedent over science, you get the image both in the minds of the student, the teachers, and the home that science is secondary.

We know that science is a great avenue for language development and much of science and probably mathematics, too, is somewhat, I do not want to overstress it, is somewhat independent of language. In other words, it is universal. And many of the cognates of scientific terms, as we all know, are very much the same in various languages.

Students can learn science from day one regardless of the language that they are operating in the rest of the school day. So we need to keep the science strong and extensive for those students because it sets a pattern, it sets a model, and it sends a message to the community as well as to the school. And I think it probably enhances their total education.

So often we take a very narrow view of what should be the education diet of students who come in with what we call limited language proficiency and we say, you know, science has to wait.

ENGLISH AS A SECOND LANGUAGE

Mr. NYE. Exactly. It has to go in parallel. In fact, one way to reach a person who English is a second language is through science. Very compelling study done in Nevada about this, and that this is a way to teach words is with these phenomena that you observe in science.

Once again, I do not want to sound like a broken record. That may be an older reference. A skipping CD, an older reference, a tapping the double arrow to the left. But elementary science is what we can emphasize at a very reasonable price that I claim will change the world.

Mr. SERRANO. Well, we thank you for your testimony.

Mr. Chairman, I have to congratulate you on the hearing and on these two witnesses. I think that this is an issue that has to be discussed, has to be debated. And as we move along to try to save the economy, we cannot lose sight of the fact that other things have to be done at the same time. And this is one of them.

And I am going to take, Mr. Nye, your comment about the kitchen to mean that your next show will be on the Food Channel.

Mr. NYE. We have talked a lot about the science of cooking to kids.

Mr. SERRANO. Exclusive.

Mr. NYE. Yeah. That there are certain techniques and good laboratory skills are closely related to good kitchen skills, not to, how to say, expand this into two heavy a discussion, but learning not to spill things very much, learning to have your hands clean, learning what chemicals or what ingredients go in first and how to prepare them. It is very closely related.

And just to talk some more about me, my mother who was, as I say, recruited, I am not sure you were here, was recruited to work on the enigma code because she was good at math and science. She strongly emphasized that, kitchen skills.

Mr. SERRANO. I was here at the hearing. I was not here when she was recruited. I was in Puerto Rico wondering if I would ever come to the U.S. and become a congressman.

Mr. NYE. Well, it is great to see you.

Mr. SERRANO. Thank you so much.

Mr. MOLLOHAN. Thank you, Mr. Serrano.

Mr. Honda.

MR. HONDA QUESTIONS

Mr. HONDA. Thank you, Mr. Chairman.

I really appreciate your enthusiasm and the comments you make about the importance of teaching and science. And you are right. I taught kitchen chemistry and all I did was tell the youngsters that they understand what they are doing. We just put a different terminology on it.

And so there are ways to make science interesting and—but I will make one clarification. It is easy in the front to teach youngsters from different language groups science, but they have to have comprehensible input. And so we need to use the language they understand best in order for them to formulate the concepts and then from there when they learn English better, they can speak about it in another language.

But science is one of the best and most interesting ways of engaging a youngster in learning. And I think that you are right. Science is really basic in terms of understanding the world around us and appreciating both differences and similarities.

And I am just fascinated with all the new information that comes out that tells us we are closer to each other, including the other primates, if we looked at our DNA. And so there must be something out there that is trying to tell us that we are all connected somehow.

The enthusiasm is what I really want to hang on to and the experience about giving teachers support is critical. And I think that while we talk about supporting teachers and making sure that they are well-informed and well-trained, we need to remember that youngsters are the primary reason that we are there, that children, they are the goal and they are the reason that we are there as far as an educational system and that if we understand that youngsters only come to school with one currency, and that is time, that maybe we will be a little bit more serious as a society to make sure that the youngsters, that we as adults do not waste their time because we cannot take their time and bank it and then withdraw it later.

And so we need to prepare both intellectually in content and also in approaching the youngsters in how they come to us. If it is language we need to use as an instructional tool for conceptual development, then that is what we need to do.

And so I would urge us to look at as we struggle with the policies of science education that we remember the child is the purpose that we are there for and no parent regardless of what background they come from will ever condemn us for looking at youngsters in that way.

I think you bring a lot of interest and smiles and things like that to science and to education, but I think that, in that skill and that ability and that opportunity that you have that we also, remind ourselves about the child, including the instruction, but the child and all the different ways the child comes to us and challenge ourselves to not only look at teacher instruction, but infrastructure of the classrooms and how we assess them. And that assessment is the end product. Curriculum is the treatment.

So for assessing the child's achievement, if they do not achieve well, then we should be saying we failed, not the child failed, that the kinds of treatment that we provided the child or the assessment missed the boat.

So with your vast exposure, the question I would like to ask both of you is in the realm of public education. Where does equity fit in terms of providing the kind of education we want for all our children and where are we on that debate of equity and where does that fit in terms of policymaking?

EQUITY IN SCHOOLS

Mr. NYE. By equity, you mean from school district to school district or do you mean people from different backgrounds?

Mr. HONDA. It probably is all of that.

Mr. NYE. Well, I would say this is where good national standards would help everybody. If we had good national standards that were not too burdensome, then this is a case where people at the local level can evaluate the kids who are coming to their school and address their needs individually and still have success at getting them excited about science, getting them to embrace science as an important part of their lives.

So if I understand your question, it is empowering officials and teachers locally with guidance and, if I may, funding provided federally. And so this balance between local authority and national authority is what I think we need to work on and where I think No Child Left Behind had some trouble was requirements without the authority or the ability or the resources to meet those requirements.

Mr. PRATT. You almost answered the question, but let me phrase it in my way and refer to your kind of description.

Number one, I think we have to have equal expectations and that is where Bill is absolutely correct. The standards and assessment across this country in the name of federal legislation are not equal. They are too diverse. I mean, all you need to do is read the reports that six percent success in one district is a 94 percent success or state in another State. So that is not equity to begin with.

But assuming we have that, and I think we can achieve that if we just have the political will to do it, then we have to think about the students themselves. And I think we have to be very careful of how we think and define equity. And we must think of equity not just as input or to use your word treatment, we have to think about equity of achievement or equity of output.

And that means when the output is not what we would say is equal across all groups of students, then we have to upgrade, increase, improve, and I will use your terminology, the treatment, the instruction, the support, the time spent with those students. That is what we have to think about.

So part of our problem is simply the inability to carefully and I think equitably, if you will, define equity, not as input, but as what students achieve or to put it in almost engineering terms, the output.

Mr. HONDA. Mr. Chair, if I may, the last comment or question, what if we assess each child at the age of three or whatever assessments we have at hand and funded each child accordingly, would that be equity?

Mr. NYE. I think it is rhetorical. No. I mean, it does not sound like it.

Mr. HONDA. What would it——

Mr. NYE. It is like, if I understand, it is analogous to one vote per person. You are saying you want——

Mr. HONDA. No. No. That is——

Mr. NYE [continuing]. To give them a gain or——

Mr. HONDA. No. That is parity.

Mr. NYE. Yeah. That is what I am saying.

Mr. HONDA. I am saying if you assess each child and each child is different, therefore each child needs different kinds of attention and resources, then there would be different amounts of money and efforts behind each child. And if that is the case, then are we meeting that child's needs, at least developing a road map for the child that is pertinent to that one child? If we go through each child, would that be considered equity?

Mr. NYE. I would have to give that some thought, but this I can tell you. The so-called individual lesson plan, the ILP, has become a real burden for many teachers because there is an effect that may not have been anticipated where one student has an individualized lesson plan. His or her parents find out about it, his or her parents of another student find out about it and they want an individualized lesson plan for his or her student. And then it becomes a burden.

So this is where once again—I am not sure I am addressing your question directly, but I will give us something to think about—once again, we need standards that are useable for a very large number of students so that it is equitable.

Mr. HONDA. So it is burdensome for us to——

Mr. NYE. Right now.

Mr. HONDA. No. Is it burdensome for us to understand that each child has different kinds of needs and developing an individual plan for each child is not necessary or does not go towards equity because it is burdensome on the system? Are we worried more about the system and the infrastructure and the cost of it or are we worried about figuring out what the child needs?

It challenges us to, as a policymaker, to step outside the box and rather than being confined within the current structure, and I understand the current structure is that we end up having parents and school boards fighting for the best interest of the child and spending a lot of money, that is burdensome, and, yet, the time of the child moves on and on and on. We know good and well through the assessment what that child really needs, but we cannot afford it.

Now I am asking a question, you know, should we be challenging ourselves as a society to find ways to make that affordable?

Mr. NYE. Well, here is the thing. Think about your favorite teachers. They were passionate. And I claim that very good teachers had a feel or an intuition or perhaps it was cognitive, they thought about it and made notes, where they provided each child with an individual lesson plan, where they taught each, they still—they taught—they do teach each child individually. Each child, they engage each child and they give that kid what he or she needs.

What has happened right now, and I think we have an opportunity to make things better, is that intuition now has to be documented, it has to be spelled out, and records have to be kept. And that is costing the teacher the most precious thing he or she has, his or her time.

And so that, I think, as I understand it, these are anecdotes from people I have spoken with over the last, let us call it, 12 years, this is something we could improve.

Mr. MOLLOHAN. Thank you, Mr. Honda. Thank you very much.

QUESTIONS FROM STUDENTS IN AUDIENCE

Mr. Bonner has made an excellent suggestion, Mr. Bonner of our Subcommittee, who I will be calling on in just a moment, has made a suggestion that we have a lot of students here. They are particularly interested in this hearing. And we want to offer them an opportunity at Mr. Bonner's suggestion, which I think is an excellent one, to ask the panel a question.

So I would invite the students here today on a piece of paper to write a question, one each to Mr. Nye and Mr. Pratt. And we will probably draw out of a hat, I am not sure exactly how we are going to do that, and ask the students' questions here.

So I think it is an excellent suggestion from Mr. Bonner.

Mr. NYE. That is fantastic.

Mr. MOLLOHAN. And we——

Mr. NYE. Now, everybody, you could text it to me.

Mr. MOLLOHAN. Well, whoa, Mr. Nye.

Mr. NYE. So you have used this technology, right, where the——

Mr. MOLLOHAN. Mr. Nye, I do not want, Mr. Nye, I do not want to lose control of this.

Mr. NYE. I am sorry.

Mr. MOLLOHAN. I know you are high tech here, but I think——

Mr. NYE. I think that is not appropriate. I think they have to go—this is the technology involving a tip and a paper.

Mr. MOLLOHAN. Thank you.

Mr. NYE. Yeah.

Mr. MOLLOHAN. Thank you for your help. Thank you.

Okay. So we invite students to do that. You do that. Then we will collect them and at the appropriate time, but in the middle of the hearing, we will not wait until the end——

Mr. NYE. That is great. Thank you.

Mr. MOLLOHAN [continuing]. We will ask those questions.

Mr. Bonner.

MR. BONNER QUESTIONS

Mr. BONNER. Thank you, Mr. Chairman, and thank you for accepting that suggestion.

I am going to try to get my question out first and then tell you a little bit about why I asked it because a lot of times, politicians like to pontificate and then give you just a second to answer the question.

SCIENCE EDUCATION COMPONENTS

Two things. What can we do to use the sources of young people today for information, internet, video games? When I was a child, it would be cartoons on a Saturday morning. But what can we do, and Mr. Nye certainly, Dr. Nye certainly has found a way to connect with young people, but what can we do to expand that?

As Robert indicated, he is the father of two young children. I have got a 13-year-old daughter and a ten-year-old son and my son loves to play video games. And whether it is the Wii system or the Playstation III or whatever, what can we do to find video games that have a science education component that are also fun because to me, we have got to find a way to connect?

Mr. NYE. Mr. Bonner, I did not ask you to ask that question, let the record show. But on Monday, the 9th of March, I start something I called Solving for X which is a series. Each segment is about four minutes where I show you how to do Algebra. And Algebra and science to me or math and science are intimately connected.

And each segment is designed to appear on a small screen, on something that a modern student would have internet access to, often in a hand-held device. And you have to make production decisions associated with that.

So I strongly believe in what is called the long tail. Are you familiar with the long tail where instead of many, many—instead of, rather, a few television stations or radio stations now, it will be thousands, tens of thousands, even millions of sources on the internet?

And so I believe that the resources available to teachers on the internet are only going to expand because many of these things are not that expensive to produce and people who are passionate about it will produce them.

So the technology of education is really going to improve. And I look back, especially in physics class, at how wonderful the modern physics demonstrations are. I mean, we had good physics demonstrations, but the modern ones are just great. And this is through the advancement of technology.

And so with that said, information distributed through the internet is going to be part of every kid's world, by information, I am sorry, educational information, educational materials is going to be part of every kid's world very, very soon.

And with that said, there is no substitute for hands-on science. So as important as the resources are available for science teachers on the internet, we still have to have equipment in the laboratory where you touch things with your hands. We cannot let that fall through the cracks.

Instead of film strips, which you no doubt enjoyed, movies where you had to get the kids from the AV Department to the film through there and there was still the one part that was burned because that is where the guy was upside down and it was just great and compelling, instead of that, these—and instead of even VHS tapes and instead of even DVDs, this will all be available on the internet. And so that will expand, but there is no substitute for hands on.

And two more things. It is very important that we secure the internet. I know there is a lot of talk about that, but we cannot—our society is increasingly dependent on electronic communications. We have to make sure that that is always working.

I mean, the electricity going out is to me as a guy who grew up in the United States is still kind of an embarrassment when the electricity goes out. But when the internet or electronic communications go down, it is going to be not just an embarrassment, it is going to be economic and in a sense educational disaster.

So how many people, may I ask the Committee, how many people know Tex Johnston? Anyone familiar with Tex Johnston?

So Tex Johnston was—I was a Boeing engineer for a few years and Tex Johnston was a Boeing celebrity. He still is. In 1954, he took a 707, which is a larger airliner. In those days, it was before the 700 designations. It was the dash 80. And he flew over Lake Washington in Seattle where, the estimates vary, about a hundred thousand people gathered for something call Sea Fair, Seattle Fair. And he performed a barrel roll with a 707.

I do not know how many airliners you have been on, but they very seldom perform rolls with those. And he landed. The bosses asked him, I am sure there were some expletives involved, Tex, what were you doing. And he said, first of all, I am selling airplanes.

It was a very compelling demonstration. But then they asked him how did he know that this maneuver would work with such a large aircraft not really designed for inverted flight and so on. And he said one test is worth a thousand expert opinions.

And so doing things for yourself once is worth being told about it a thousand times. And so with the internet, we can distribute this information. We will distribute algebraic sample problems, but you still have to do them for yourself. We still have to provide people the resources to do them for themselves.

It was an excellent question. Thank you.

Mr. BONNER. Since it was an excellent question, I will just stop at that one then.

Mr. NYE. Thank you.

Mr. BONNER. Thank you very much.

Mr. MOLLOHAN. Thank you, Mr. Bonner.

We will have one more questioning and then we will—we are sorting through the students' questions now and then we will ask a student question.

Mr. Fattah.

SCIENCE FUNDING

Mr. FATTAH. Thank you very much.

Let me first say that I agree that I think things are going to get a lot better very soon. The President has said that science is going to be at the very front burner of the Administration's concerns around a range of issues.

But our Chairman has done a great deal in the area that we are talking about this morning as Chair of this Committee. I think we have invested a great deal of money under the Chairman's leadership in trying to improve science education and to respond to some of these issues. And I want to publicly thank him for that.

But whether the youngsters in, you know, west Philadelphia, in my district, or West Virginia, the Chairman's district, or in the Bronx or throughout the country, I mean, one of the challenges that we have is illustrated in your testimony this morning about the lack of content knowledge, particularly by teachers who are teaching children in some of our more disadvantaged school districts.

And, you know, the wealth disparities between school districts, a lot of people say do not matter. It does not matter if we spend three times as much on one kid as another for 12 years, somehow they should all end up with comparable results.

But the truth of the matter is that I think we know better and that it does matter. And the need for additional professional development, the need for teachers with improved content knowledge is important. The other reality is the physical plan itself. There are schools, you know, in our states that, you know, a science laboratory is not something that one can take for granted.

A few years ago, the Washington Post ran a story and they talked about a group of kids in a large urban city who went out to the suburban school district to visit the campus and the kids from the suburban school came in and visited the campus of the school in the city.

And they described these two circumstances in which at one school, there were these, you know, very nice science labs and all of the science and math. Faculty had advanced degrees. And they described the other school in which there was no microscope that worked and there was no, you know, no equipment of any utility and that none of the teachers teaching the core subjects of math and science had majored or minored in math or science.

And you do not have to be a rocket scientist to figure out where one school was versus the other. I think we all know. And one of the real fallacies of No Child Left Behind is that it suggests that somehow we should get a comparable result when we do not have a comparable opportunity for our young people to learn.

And so I think that this question of equity is important, but I wanted to talk a little bit about something else that was raised in your testimony, Mr. Pratt, about national standards.

You know, we also operated under, for the entire country's history, you know, under the notion that somehow there is some local, you know, physics or biology or that somehow science taught in Philadelphia and Mississippi, somehow should be a different science than taught in Philadelphia, Pennsylvania.

The push for national standards has always been fought by those people who say that, you know, we should have local control of schools and people at a local level can decide how smart or less than adequately educated they want their own children to be and that there is no national imperative, to use President Nixon's phrase, to worry about the quality of education.

I think that now that we have arrived at this moment, we all know better and that we do need to have a set of national standards.

But beyond that, I am interested in whether we could create a national model of what should be being taught at what grade levels, what kind of physical facilities should be available for the teaching of science, and what exact prerequisites should be for science education.

And to conclude, where there are strict standards for science educators, like in Pennsylvania, they are enforced, but there is some selective amnesia. That is, when you get to a city like Philadelphia, what is done is applications are made for waivers from the teaching requirements so that they can get a warm body in the classroom because they cannot afford to hire a qualified science teacher under the state requirements of what that teacher should know and should be competent to teach.

So we have this situation throughout the country. That is, we have requirements. They are waived in the situations in the schools where kids need the most help and they actually get the least. And we have to deal with the consequences.

So I am happy that the Chairman had you come in today. I would be interested in your comments.

Thank you.

NATIONAL STANDARDS

Mr. PRATT. Well, several comments. I participated and was on the staff of the National Research Council during the development of the national standards in the mid-1990s and we listened to a lot of people at the community level, political level, as well as the educational level.

One of the strongest segments of our community that supported the idea of national standards, which was very innovative in those days, it was just coming almost out of nowhere except for the work that that NCTM had done in mathematics a few years earlier, where what we might call the underprivileged, under-represented, the minority communities, those were the strongest supporters of national standards because they said at least we are going to get some attention.

And part of what goes on, even though there are waivers, even though there are exceptions made either politically or administratively, at least we know what is going on now. We can identify the problem. That is the first step. Before that, we could not identify or we did not, we did not have the political, educational, or personal will to identify the problem.

So I do not think that is the end of it. That does not solve it. I do not want to leave you with that impression, but at least we know now. And so we are hyperconcerned and aware of the learning gap and the problems of inequity in the districts across it because of standards and because of assessments.

I think we have not pushed that far enough and that is why many of us believe that national standards and national assessments would help us become better informed and better aware of the problem. That does not mean we know how to solve it, but that at least is a first step in doing it.

Mr. FATTAH. I have paid a lot attention to school equity, adequacy issue over the years.

Mr. PRATT. I am sure you have.

Mr. FATTAH. And it has been litigated in many states around the country. You know, if you go and look at the Arkansas case, there is an affidavit from a great teacher, name is Roy King, and he says that he is the entire science and math faculty at his high school of 200 kids.

He did not major or minor in math or science. He actually got hired to be a gym teacher, a physical education teacher. And he makes 20 grand and he makes a few more dollars driving the school bus. He said he loves these kids, but they actually deserve a little bit better than they are getting. He has got 20 textbooks for 200 kids. He has got four calculators and he has not seen a microscope in school. Now, this is what he affirmed to the court.

And it is just a challenge for us to think about how we are going to get from where we are to where we need to go, you know, unless we create not just the aspirational standard but the resources and the political will to actually make sure that these kids get a fair shot at it because, you know, there is a lot of talent out there, but it is not going to be developed unless they find an inspiring teacher who is competent in what they are teaching and has the opportunity to mine those gems.

Mr. NYE. Well, there has been a lot of talk about audacity. And I think this is the time to take an audacious step. And that is the United States is going to be the best at this. And if we make that part of our thinking, it will affect, in my view it will affect everyone. It will affect every educator, every administrator, every school board, every voter.

And as you may know, I grew up in Washington and so I am sure they are all very nice people. I am sure they are lovely people, but I grew up kind of, if you will, hating the Baltimore Orioles. I am sure they are fine people. I say this is not my fault.

But with that said, I have tremendous respect for the manager, Earl Weaver, who said if you play to win by one run, you are going to lose by one run. If we spend a lot of resources at your level mincing these details, I think we can get bogged down.

If we all just decide that the United States is going to be the best in the world in math and science, we are going to graduate the best engineers in the world and we are going to lead the way, if we all decide that we are going to do that, then that will trickle down.

I had a very limited exposure. I spent some time with several people who investigated the Columbia space shuttle wreck. And if nothing else, they found that you have to change things at the top to change things. You have to change things throughout the organization to change things. And those changes start at the top.

So I think that if we just say we are going to be the best in the world, we are going to do whatever it takes to graduate the best engineers and scientists and we are going to start in kindergarten, maybe even pre-school and work our way up, we will achieve it.

But if we say, well, we cannot do this or we cannot do that because this school district is concerned with this and this school—sooner or later, it will bog down. We have got to all decide this is worth doing.

Now, I know we are all very, very concerned about the economic situation. That is all we talk about along with apparently the color of the President's hair. But I claim, and I do not think it is an extraordinary claim, that ten or fifteen years will be here before you know it, ten or fifteen years, about the time people are hoping to resolve this economic crisis for sure. Some claims are two or three years, but I think those are extraordinary claims.

By the time that economic crisis settles out, we will need to lead the way. And that leadership in the developed world comes from technology. And that technology starts with elementary science education.

I know these are easy things to say. But as you see, I really believe in it. And I think if we start right now from the top, we can change the world.

Mr. FATTAH. Thank you very much.

Thank you, Mr. Chairman.

STUDENT QUESTIONS

Mr. MOLLOHAN. Ranking Member Wolf is next up. He has graciously deferred to the student question. So I am going to ask one student question and then I am going to give him the three that I have in my hand. All of them are really good and I would like to ask them all. And then he can ask one of these questions as a part of his.

Perhaps we can, you know, be distinct in answering these questions. Of course, we have several of them, but I invite each of you to respond.

The first question, and these all are really excellent questions, I mean, it is impressive, from our students in the audience, most specialized funding in science focuses on students who are behind. Do you think this should remain the focus or should funding go toward students who are interested in advanced learning?

Perhaps first we should ask if you all agree with the premise of the question and then if you agree with the premise, do you think funding should be directed to advanced learning?

Mr. Nye.

Mr. NYE. I do not have the statistics on that, but I will say anecdotally if not the most funding, the most of a teacher's time and so the perception might be the funding is to what might be called distractions or trying to bring people up who have not been exposed to science from an early age, trying to catch them up certainly can take a lot of teachers' time. And that may lead to the perception that the advanced students are not getting their due.

But I will tell you also from my personal experience that if you can excel in math and science, you will be recognized and you will find your way. So that is as we say in engineering susceptible to analysis. So I think we should look into that.

Do you have knowledge of that, Mr. Pratt?

Mr. MOLLOHAN. Thank you.

Mr. Pratt.

Mr. PRATT. First, the premise. I mean, you know better than I do that their funding formula is based upon the economic level of the states and communities. So whether that is what the students intended, you know better than I do that there are formulas applied to virtually all flow-through money to states and to districts.

Now, whether that should be a national priority is, of course, the question that we come back to when the equity question hits the table is where does the money come from. And somebody is always going to tell you if we put it in favor of this group in the name of equity or whatever the label may be, it probably has to come from some place else.

We do not like the fact that there is a zero sum game when it comes to appropriations, but you know that far better than I do.

So the question we have to grapple with is probably not so much at the individual student level, although we cannot lose sight of the importance of individual students, but ask the question as a country, what is going to serve us best, what is going to serve us best to educate to the ultimate degree a few elite students which seems to be somewhat the tenor of that question, I do not want to over interpret the question, or do we face the equity issue and think about all students because one of the premises behind the funding formulas of today is that we need more. We also need quality students. We need more.

And if we do not, I hate to use the word harvest, but if we do not gain more graduates from all groups of the population, we are losing out as a country. We are losing out technologically. We are losing out socially. We are probably losing out competitively across the world.

Mr. MOLLOHAN. Two members have not had a chance to ask questions yet, Mr. Wolf, our Ranking Member, and Mr. Ruppersberger. We have a vote. That means we have 15 minutes. I think we can get both in.

And I call on Mr. Wolf right now.

MR. WOLF QUESTIONS

Mr. WOLF. Thank you.

I wish I had been here for the whole time. My district is right here and I have had constituents coming back and forth in my schedule, so I apologize.

I have a number of questions. Maybe we will just submit them for the record.

Two of the students' questions, I think, is very good. I think, Mr. Nye, maybe you triggered the one, but he or she said as an August 2008 engineering graduate, I declare myself an "expert witness." He said you mentioned burdensome standards. What good is a standard if it does not create a burden for a student to meet it, which I think is a very good question?

Mr. NYE. Well, the burden is not the student. Yeah, the students have to work hard. When I was in school, we did a lot and so on. No. The burden is on the teacher. That is what I was referring to, where especially the elementary teacher right now is required to perform a lot of assessment, at least as I understand it from teachers themselves, required to perform a lot of assessment and that assessment and reporting in a way that does not enable the teacher to inspire kids.

Mr. PRATT. I am not sure the reference to burden, but I did want to almost respond earlier when my colleague referred to the burden in the classroom when expectations are increased or when individual student needs are emphasized.

I think we have to think of burdens or when we hear the word burden or we hear the word that I do not have the time or it is an unfunded mandate, we need to be sure that that is not really the case where an expectation is being laid upon a district and, therefore, teachers without the kind of support necessary to do it.

So it may be an indicator that we need to pay close attention to. And we all have a tendency to kind of complain, if you will, and be overworked, I am sure, but I think there may be a signal there that we are not attending to. And that is the lack of support to carry out what is otherwise an excellent, excellent idea, but does demand more effort, more time, and, therefore, probably more money on the part of the district.

Mr. WOLF. The other question, and, Mr. Nye, you mentioned No Child Left Behind. I am not an expert on education. Four of my five kids are in education and I am the parent of five kids.

Without No Child Left Behind, the inner city schools are in decay. And I think the No Child Left Behind has helped. And if you look at some of the figures that have come out, particularly for inner city schools, they have made a tremendous difference.

So how it should be, there should be more discretion, more flexibility, but there have been fundamental cities and places whereby the kids have been neglected for years. And I think those standards have made a difference.

And in my own area, to a certain population, they have made a fairly good difference. But it should be more flexibility, I think.

The other question is, our teachers are very passionate about science, but what can you do about most, and they underline most, of all our principals and administrators who do not get it? I think that is why many teachers do not stay in the profession.

Mr. PRATT. As one who worked in administration in a school district for 32 years, they should be part of the professional development also. Do not just focus on the teachers. I mean, administrative support in a whole variety of ways, whether it be financial, moral, or educational is, critical. It is extremely critical.

We all know that in the workplace, any place, the leadership, who you are working for, who you are responsible for sets the tenor for where you are, sets the level of expectation and the quality of what goes on in that workplace, whether it be schools or anything else.

So let us not leave the principals and superintendents, if you will, out of the professional development equation when it comes to support.

Mr. NYE. It comes from the top.

Mr. PRATT. Yes.

DC VOUCHERS PROGRAM

Mr. WOLF. Well, speaking, just to take an opportunity to put this on the record on the top, I listened to my friend from Philadelphia talk about the D.C., about the Philadelphia schools. I am a graduate of the Philadelphia schools. Let me just send a message to Mayor Fenty. And you said you were here in the District of Columbia.

The District of Columbia, the Congress in its wisdom with Congressman Davis put in a voucher program for kids in the inner city to have an opportunity to go to other schools. Ten thousand are using that. To the credit of the Washington Post, they have editorialized twice against the Congress for abolishing and ending that.

And, yet, the strange thing is Mayor Fenty, who has done a great job with regard to the new superintendent Rhee, I have been very impressed with her, Mayor Fenty has been silent as these youngsters are now going to be forced out of these schools that they have taken advantage of the voucher and have to go back into the district schools.

So when you talk about the principals and the administrators, where is Mayor Fenty on speaking out on the issue of whether or not this should continue because 10,000 kids are going to be forced out of their environment and the schools that they are into back into schools that may not be going very well.

But I am going to have a number of questions that we will then submit for the record. And I thank the Chairman for the hearing and yield back, unless you want to comment on Mayor Fenty not speaking out on the issue.

Mr. NYE. Well, if it is Nationals versus Phillies, I am Nationals.

Mr. WOLF. The Phillies and Robert Roberts was a better pitcher than anybody on the Nationals.

Mr. MOLLOHAN. We have ten minutes or eight minutes 28 seconds. Mr. Ruppersberger——

MR. RUPPERSBERGER QUESTIONS

Mr. RUPPERSBERGER. Well, I assume your——

Mr. MOLLOHAN. Excuse me just one second. I will ask the witnesses if they can stay, we have four votes, if they can stay until after we vote. And can you?

Mr. NYE. Absolutely.

Mr. MOLLOHAN. Okay. That will run us a little past twelve. But I think it is really an important hearing and we want to ask a couple more students' questions. Then we have some questions we want to go through.

Mr. Ruppersberger.

Mr. RUPPERSBERGER. I assume your comment about the Orioles is that you are a Yankee fan? Is that the case?

Mr. NYE. No.

Mr. RUPPERSBERGER. But, you know, with Brooks Robinson and Frank Robinson——

Mr. NYE. Oh, it was fantastic. They were a great team.

Mr. RUPPERSBERGER [continuing]. Boog Powell.

Mr. NYE. They played with seven guys and still win.

SCIENCE EDUCATION AND THE REST OF THE WORLD

Mr. RUPPERSBERGER. Not anymore. We are working on that.

I also agree with Congressman Wolf. I think you have some great teachers and anybody in the teaching profession, I respect. And a lot of my family is in the teaching profession.

But I think a good principal is so important. You can tell 15 minutes into school and a lot of times, we do not train our principals and we do not have the right people there. But that is not what my question is.

I am on the House Select Intelligence Committee and I Chair a Committee that oversees all of NSA, all the space program, a lot of the science issues. And this Committee has jurisdiction over NASA, by the way, from a funding point of view.

And in my role there, and I have been to China and other parts of the world in the capacity of being on the Intelligence Committee, and, you know, China just about a year ago graduated over 600,000 rocket scientists, mathematicians and engineers. And because they are not a democracy, China can tell them, the smartest people, you go into rocket science, you go into this arena or whatever.

If we are going to be the nation that we are now and that we need to be, and we are slipping in a lot of arenas, so we have got to deal with it, I work with NSA and some of the people on their board, Microsoft is on their board, some pretty good people, very successful companies, and want to create a concept right at NSA in the Baltimore region to create a STEM school starting in middle school, and this is what China is doing, and really develop people in the Baltimore region, testing children to come to a STEM school at NSA where they will be able to have excellent teachers but focusing in the arena of math and science, but also the inspiration of being near NSA and NASA, Goddard is right up the street.

And we have been working with the State superintendent, Nancy Grasmick, I do not know if you know who Nancy is, and the other jurisdictions there, and wondering if you have any comments on— and I guess you probably, Mr. Pratt, might be able to answer this, but either one—on where do we go?

In other words, what—developing the curriculum for this type of operation and if it works, we want to take it to other parts of the country. This would be a pilot program.

I have been talking to the Gates Foundation and Gates, Bill Gates about it, and they are very interested in getting involved, having some of the big business community, people in the business community that are interested in STEM and developing our math and science. But we have to start early.

The subjects from K–12, that we want to start this in middle school. What do you think is necessary to lay the foundation and what type of curriculum should we pursue on the focus of what I have told you?

Mr. PRATT. Well, there is a caution involved here. In some respects, the kind of curriculum is not that different than all students should experience. Maybe the rate and the level of abstraction, the age in which ideas are introduced can be modified based upon the special experience and motivation and ability of those students.

But I think there is a caution here that we do not want to be too symbolic. We do not want to say we are doing this in the name of STEM for a few students and, therefore, we have, and you did not imply this, but we have solved the STEM problem.

PILOT PROGRAM

Mr. RUPPERSBERGER. We wanted the pilot program to take it throughout the whole country.

Mr. PRATT. And it can set a model, but it also sets a model that sometimes is not the most appropriate because there is always the notion that that does not apply to my students. That is not the equivalent of what my situation is.

We need model schools for the poorest of students both economically and student-wise. We need to know how to work with those——

Mr. RUPPERSBERGER. But you are giving me a macro approach. I am more interested, I am working with this project, and I would like to know what you would do to develop curriculum? What type of teachers? Would you bring people that do not have as much specialty in the area of actual teaching education and bring in some former people, rocket scientists, maybe bring an astronaut in, you know, because we are not getting the students to go into this field that we need to?

One of the issues is to have this near NSA and to have them involved in an intern type situation that this will be their goal and their motivation. This is what China does.

Mr. PRATT. Well, if you could find another host, I mean, a school full of Bill Nyes, you would solve the problem. But it is not just the astronauts. It is a combination of astronauts and teachers.

Mr. RUPPERSBERGER. No question.

Mr. PRATT. It is a combination of curriculum. It is the kind of instructional materials. It is the laboratory equipment that is available there. It is the questions that are asked of the students.

Mr. RUPPERSBERGER. It is a possibility of paying teachers more than they would normally be paid in the system. That might be a focus of where we——

Mr. NYE. If you want to attract——

Mr. RUPPERSBERGER. Yes, go ahead.

ATTRACTING QUALIFIED TEACHERS

Mr. NYE. If you want to attract people who would otherwise go to NSA to teach in the school, I imagine you are going to have to pay them somewhat more than you would pay other——

Mr. RUPPERSBERGER. And that is why we want the business community involved, to help us in that regard.

Mr. NYE. So along that line, if you want the very best science students to attend this school, I believe you have to start at the elementary level. You have to support elementary science education before you start this filter or sieve or selection process for these people to go into that school.

Mr. PRATT. At the risk of keeping Major League baseball on the table, you need a farm team.

Mr. NYE. Yes.

Mr. PRATT. You need a development team at the elementary and middle schools.

Mr. RUPPERSBERGER. Well, we need to take this type of curriculum to the whole country. And there are some areas of the country that do have pretty successful, but a few——

Mr. NYE. Well, Bronx Science.

Mr. RUPPERSBERGER. Bronx Science?

Mr. NYE. Yes. That is——

Mr. RUPPERSBERGER. So you are a Yankee fan then, right?

Mr. NYE. No, no, no, no. Heavens.

Mr. RUPPERSBERGER. I agree.

Mr. NYE. No. But this is a very successful model, the Bronx School of Science, you know, where people in the New York school districts compete to go to a technical high school. But my claim is that you have to start before people are in high school. So if you want the best people in middle school, you have to start before.

Mr. RUPPERSBERGER. That is interesting because we debated that back and forth working with the superintendent of Maryland.

Mr. NYE. I will claim you ask anybody who works at the NSA in a technical position, there are probably, I do not know, tens of thousands of these people, when did they want to be scientists or engineers, when did they want to be computer scientists.

Mr. RUPPERSBERGER. Most of them, very early, and I have had——

Mr. NYE. I was going to say it is going to be before they are ten.

Mr. RUPPERSBERGER. Yes.

Mr. NYE. And the example I always give you is ask your physician, ask your doctor when did he or she want to be a doctor. It was long before they were ten. They will tell stories, yeah, I was looking at plants.

And just my own experience, I used to watch bees. And then I read in Ripley's——

Mr. RUPPERSBERGER. Then you got stung.

Mr. NYE. I got stung many times, yeah. It has not affected me. I read in Ripley's Believe it or Not that according to aerodynamic theory, bees cannot fly. And even as a very young person, I realized that was a bad theory. Bees do really well. I mean, they outperform helicopters pretty much.

And so this passion and this interest happened long before I was in sixth grade.

Mr. RUPPERSBERGER. That is a great point. I have learned something here today.

Mr. NYE. Well, good. I have learned a great deal.

Mr. RUPPERSBERGER. Do you always wear a bow tie just like you are branding?

Mr. NYE. Yes. I wear a bow tie for a couple reasons. They do not slip into your soup. They do not flop into your flask. And I——

Mr. RUPPERSBERGER. I like it. It looks good on you.

Mr. NYE. Well, thank you. Thank you. And——

Mr. RUPPERSBERGER. You started with the Orioles and I am just trying to play with you.

I am finished my questions. How much time do we have before the vote?

Mr. MOLLOHAN. I would advise the members of the Committee we have 17 seconds.

Mr. RUPPERSBERGER. Okay. I really want to thank you.

Mr. MOLLOHAN. And probably scientifically it is impossible to get over there.

Mr. RUPPERSBERGER. And I think what you do, you are right on course.

Mr. NYE. Well, thank you.

Mr. RUPPERSBERGER. Keep doing it.

Mr. NYE. Let us change the world.

So we wait here while everybody votes?

Mr. MOLLOHAN. Yes. You can wait here, take a break. We will be back. We have four votes. The next three, I assume, are five minute votes? Five minutes votes. Probably 20 minutes——

Mr. NYE. We will be here.

Mr. MOLLOHAN [continuing]. Before we get back.

Mr. NYE. Sir, we are here.

Mr. MOLLOHAN. Thank you. We appreciate it.

Mr. NYE. Thank you.

[Recess.]

Mr. MOLLOHAN. I thank the witnesses for their accommodation. We will continue the hearing with Mr. Wolf.

STARBASE QUESTIONS

Mr. WOLF. Thank you, Mr. Chairman. Just a couple of short questions.

Are you familiar with the STARBASE Program at the Department of Defense, either of you? You are not?

Mr. NYE. No.

Mr. WOLF. Okay. Well——

Mr. NYE. It is an education program?

Mr. WOLF. It is an education program. We can——

Mr. NYE. Does it have an acronym?

Mr. WOLF. It is a premier educational program sponsored by the Office of the Assistant Secretary of Defense. It provides students 20 to 25 hours of stimulating experiences all on the sciences. It is geared toward fifth graders. It says focus on elementary students, primarily fifth graders. The goal is to motivate them to explore science, technology, engineering, math, STEM, as they continue their education.

I thought you would have known. I think it was started by Senator Byrd, I believe. And we are going to bring it to my district. Well, why don't you look into it? We will get you the material.

Mr. NYE. Did you say 20 to $25.00?

Mr. WOLF. No. Twenty to 25 hours.

Mr. NYE. Hours, oh.

Mr. WOLF. Yes, it has to be done at a defense installation. And we are going to be doing ours at our Armory, but they do it at the Air Force Base in Martinsburg. Well, take a look at it and we will get you the material.

The other one is your comments about the Jason Program? Are you familiar with the Jason Program?

Mr. NYE. Yes, sir.

Mr. WOLF. Yeah. Could you tell us a little bit. We have it in my district. They are now based out in northern Virginia. I have been very impressed with them and Dr. Bell. What are your comments.

Mr. NYE. Well, to me, it is maybe the perfect example of informal science education. Informal being defined as something not in the classroom. So you might think of it being rigorous and stuff when you are kid in the Jason Program, but it is generally outside of the curriculum. And to my understanding, it is very successful.

Mr. WOLF. Well, I think it is now part of the curriculum. We have it in a number of schools in my district.

Mr. NYE. Well, that is good.

DR. BELL

Mr. WOLF. Well, do you ever talk to Dr. Bell? Do you know if——

Mr. NYE. I spent some time with him.

Mr. WOLF. Yes.

Mr. NYE. He is very gracious.

Mr. WOLF. Yes.

Mr. NYE. And you talk about a compelling guy.

Mr. WOLF. Yes, he is very, very impressive.

Mr. NYE. And he is a classic example of someone who is very passionate.

Mr. WOLF. He is, he can excite kids.

Mr. NYE. I know that this Committee is responsible for funding NASA. Dr. Bell really emphasized the importance of studying the ocean.

Mr. WOLF. Yes, NOAA too. I do not know what this Administration's budget will show. The last Administration was not very, very supportive of it. And I just wanted to get your comments. I am glad you think it is a good program.

The other two questions quickly, do you think there should be some legislative provision that is put into law saying that any company, scientific company, Lockheed Martin, Raytheon, Boeing, that has government contracts must have a number of its employees donating time in the schools, scientists, because we find out in northern Virginia when SAIC or a company has its people coming into the school with a real hands-on program, a robotic program, if you will, but they are all doing it on a voluntary basis?

Do you think it would make sense to either give a tax credit or put in the government contract that if they participate in any government contracts, then—I mean, Boeing lives off of government contracts—that they have to have so many hours of their employees to go into the schools where they live and to teach?

Mr. PRATT. I would strongly support that. I had some personal experience a few years ago in one of my earlier retirement positions. One of my jobs was to align up local scientists and engineers to go into elementary schools on somewhat of a regular basis to kind of give them a surge of elementary science, if you would.

So my job was to find volunteers anywhere I could, at the university level, at the hospitals, and especially in local aerospace industry.

One of the biggest problems we had was to get the release of engineers and scientists who had government contracts. It was just the opposite. They had to account for every obviously minute or hour and assign that to each project they were working on.

And so the administration, the management was very hesitant, if not resistant, to any kind of release because there was no place to charge that time. So I would strongly support the idea.

Mr. WOLF. If I could ask you to give me a letter to that effect, and what I will do is I will contact the Department of Defense. Maybe if the Chairman is willing, we could put some language in, but to sort of say, because I think many would like to do that and, yet, on a procurement basis, they have a difficult time, to say that if you are participating in any government contract, so many hours, if you will, going in practical in the classroom. So if you could give me a letter to that effect. Do you——

Mr. PRATT. This is not recent experience, but I would be glad to do it.

Mr. WOLF. No. But just saying how important that is.

Mr. PRATT. Oh, support the idea, definitely.

Mr. NYE. For example, sir, in NASA, we have a civilian space mission.

Mr. WOLF. All right.

OUTREACH EDUCATION PROGRAMS

Mr. NYE. You are required typically to have ten percent of the budget go to outreach education.

Mr. WOLF. I did not know that.

Mr. NYE. Well, it is quite common. Anyway, my point being it sounds like there is an opportunity here where they do not want your government to contract you or reluctant to release an engineer to go teach in school. And you will find many engineers who are very enthusiastic about this. Maybe there is a way to change the accounting so that that could be credited toward their outreach budget.

Mr. WOLF. Well, let us look into that. But I would appreciate a letter validating as much as you feel comfortable doing.

Mr. PRATT. Oh, yeah.

CHINA VS. U.S. IN SCIENCE EDUCATION

Mr. WOLF. The same with you, Mr. Nye.

The other, if you had to compare us with China, how we are doing in sciences in the schools, do you think we are doing very well, do you think we are kind of holding our own, or do you think we are in decline?

Mr. PRATT. There was an article in Science Magazine, a AAAS publication, maybe two weeks ago, a little education form article that compared achievement in three or four different areas and content knowledge and showed us very far behind, very far behind, lacking——

Mr. WOLF. Who was?

Mr. PRATT. The U.S. compared to China. It was a simple sort of U.S. to China comparison.

Mr. WOLF. We will get that copy.

Mr. PRATT. There was one interesting, maybe not ironic, but one interesting finding about that. They tested in like three or four different very specific content areas, and I think in the physical sciences, engineering physical science. And we were very deficient, except their was one test on the scientific knowledge or understanding of or ability to understand the scientific enterprise.

And that particular subtest, the two nations were very equal. A bit ironic, but it may say something about the nature of science in China more than it does say about science education in China where it is so strictly oriented toward strong academic performance with very little experience in science. It was not the well-balanced education that we value so much in this country.

Mr. WOLF. Of course, they are moving so fast. How about you, Mr. Nye? Are we doing very well, we are steady, or we are in decline?

Mr. NYE. Here is what I will say. I have only been to China once, but I will say that the people you meet, these are academics, astronomers, rocket scientists, they are very hopeful about the future. They are excited about the future and they are excited about their science.

So whatever disparities exist now are only going to be exacerbated. They are only going to get worse. China, the country and the people there are very excited to lead the world. They are excited about the future.

With that said, keep in mind that about half of the people in China as of a couple years ago have never made a phone call, never made a cell phone call, never made a phone call. And so the Chinese government is working very hard to provide people with a basic knowledge.

And this might be part of why that content knowledge so called seemed to be ahead, whereas the basic understanding of science as a process was about even. It might be because they are hustling. They are working hard to get everyone caught up.

Mr. WOLF. Yes. They are surging in the space program, we have been told. We have 90,000 people in the space program, government and nongovernment. They have over 200,000. And you cannot do that for a long period of time.

I worry that our young people, many are watching more video games, probably spending more time on violent Grand Theft Auto video games that are absolutely horrible, and if you think I am right, say so, and not putting it into the math and the science and physics and things like that.

Mr. NYE. Well, about the Chinese space programs, may I comment just a little bit about that?

Mr. WOLF. Yes.

Mr. NYE. Bear in mind, everybody, that the Chinese space program and the Indian Space Organization, ISO, both of these government bodies are going to send people to the moon. They are going to try to send people to the moon. And this is an opportunity for the United States science and engineering community to work with these emerging space faring nations.

I have heard as Vice President of the Planetary Society and a science educator a concern that the United States cannot lose the next space race. And as I understand it, the space race would be to the moon. Well, the United States landed people on the moon 40 years ago.

So in a sense, the United States has already done this. And it was a time when everyone in the world was involved. Everyone in the world celebrated the landing of humans on the moon.

So this is an opportunity to use things like the International Space Station to engage these emerging space faring nations and we will do that, I claim, with young scientists and engineers. The young, the emerging scientists and engineers from both nations or all three nations can work together to explore space.

Mr. WOLF. All three being?

Mr. NYE. China, India, and the United States. These are the emerging space faring nations. With that said, I mean, the European Space Agency is a terrific thing. It is great. But they, it has not reported that it intends to send humans back to the moon.

Mr. WOLF. Well, I agree with you, but I have got to end on this for the record because somebody might actually look at this.

China is a dictatorial country that is persecuting its people. It has a large number of Catholic priests and Bishops in jail today being tortured, a large number, 30, about 30. It has a large number of Protestant Pastors.

If you need a kidney, for $50,000, you can go there. They will take your blood type. They will go into the prison and they will shoot somebody. And for $50,000, you can have a kidney transplant.

They have plundered Tibet. We know what they have done it for. They are spying against us and stealing our secrets and weapons. They have had cyber attacks against a large number of members of the Congress and also Committees.

So go into this with your eyes open. They are not going to cooperate only. They are going to be taking. They are going to be taking things. With the other countries, I completely agree. But, you know, I think everyone has this warm and fuzzy panda bear feeling with the Chinese. They are potentially a direct threat. And if they ever gain whereby they can surge ahead, I agreed with you and you have taken a little bit away, we should be number one in everything that we do. I think that is the exact thing. Too much cooperation with China will be they will take.

Now, I believe I hopefully will live to see the current Chinese government fall and there will be democracy. The Chinese people are wonderful people, absolutely wonderful people. The government itself is evil. And so to cooperate with the current government in space, they will take and they will not give us anything.

But other than taking China out of that, yes, with India, I agree and with Europe, I agree.

Anyway, I appreciate your testimony. I thank the Chairman for having the foresight for having these hearings.

I think the thing that you said the most that I believed in, if you lose them by ten, you probably lost them because you never hear, oh, maybe never is an exaggeration, but of somebody going to UVA and majoring in history and in their sophomore year transferring into physics. I mean, it just does not happen. I think your point is well taken.

Now, maybe that is where the thrust should be for the National Science Foundation and the Department of Education to really put everything, knowing that we are limited in resources, everything we possibly can first, second, third, fourth, and fifth grade with the idea if we capture them then, and I wanted to be a congressman when I was in third grade, and so I think your point is well——

Mr. NYE. It was before you were ten, right?

Mr. WOLF. Well, yes.

Mr. NYE. That is remarkable.

Mr. WOLF. Yes. I knew. They asked me and I said, and I stuttered very badly, and the class would laugh at me. They would say, you know, you cannot even speak, who are you going to be. I was in third grade in elementary school, Patterson Elementary School. And I knew what I wanted to be.

Now, I ran in 1976. I might tell you, this is not for the record, your brother supported me, he said, when I ran. He said he voted for me. This is not for the record. I lost in 1976. I lost in 1978. I won in 1980 and barely won. So your brother may be partially responsible for me getting my boyhood dream.

I yield back. Thanks.

AMERICA COMPETES

Mr. PRATT. One follow-up comment, if you would, please, allow me. A pointed suggestion, if I may. “America Competes” seems to be very much in the minds of the legislature right now. Please look at it very carefully with respect to its support for elementary science. My assessment is it is being undervalued and that particular piece of legislation.

Mr. MOLLOHAN. Thank you.

Mr. Wolf, I am not sure what good it was making those comments not for the record. We may still be on C-Span and we are being web cast anyway.

So thank you.

Following up on a couple of lines of Mr. Wolf’s questioning, this whole question of inquiry-based education versus content-rich education and the balance between the two, I know I wonder, because I guess I was not exposed to inquiry-based instruction much, so I appreciate in the sense of having experienced content-based science and math education, where does one end and the other begin? And how do you assess relative value and then, of course, where is the balance between the two? I mean, is China being successful with its approach and are we just ambivalent and searching for our approach?

And both of your thoughts on that, Mr. Nye first, please.

Mr. NYE. Well, the expression content rich is, I believe, another way of saying learning facts.

MR. MOLLOHAN QUESTIONS

Mr. MOLLOHAN. Yes, as I am using it, that is what I mean.

HANDS ON SCIENCE

Mr. NYE. And then inquiry based is another way of saying hands on or experiment or demonstration based.

Mr. MOLLOHAN. Yes.

Mr. NYE. And, of course, you need both. And I will say that at the elementary level especially, you have to experience nature and the world around you with your hands and eyes, with your senses. It is very important.

But I also claim people talk about trivia contests and trivia games and so and so being an expert in trivia. I will claim that the more you know, the more facts you know, the more trivial facts, seemingly trivial facts you know, the more you know.

And by that, there is a skeleton or a scaffold that forms in anyone's mind. As you learn about the world around you, you learn about the planets, about the size of the earth relative to the size of the moon to the sun, to the plutoid Pluto. You learn about the length of a DNA molecule relative to its width relative to a meter.

And so these facts give you a complete picture of the world. And so you have to have content rich education and you have to have hands on education.

But I believe, and now I will hand it to Mr. Pratt. I believe we have neglected both aspects of elementary science education. And that is why we are here.

Mr. PRATT. It is one of the burning questions we are all trying to face. Unfortunately, I think the dichotomy somewhat expressed in your question is an unnecessary dichotomy and we would like not to do an either/or. Inquiry is a powerful learning process of getting to information content and facts, if you will. So they very much go hand in hand. I would cite a source that I think might be useful to even read into the record, is that the NRC published very recently, in the last eighteen months, a report called Taking Science to School. And in there they cited four major goals for science education. And they pointed out, Bruce Albertson in a very recent address to AAAS and in an editorial in Science Magazine about two months ago pointed out that we only meet one of those, and the other three are missing in our education. And I will just cite those for you, quote them.

The first one he says we do a reasonable job of is to know, use, and interpret scientific explanations of the natural world. That is sort of the content of science. The other three, and in his address he put all four of these on the screen and then said, "This is what we think science education should be," and then he, the next slide the last three were x'd out or crossed out, because he said they do not exist. And I will just cite those for you. To prepare students to generate and evaluate scientific evidence and explanations. To understand the nature and development of scientific knowledge. And to participate productively in scientific practices and discourse. So we can put labels on that and call it hands on science. We can call it, as we like to almost today, call it minds on science. It is all a part of science education. It is all a part of the total education of citizens of this country with respect to science. So we do not want to see the either/or. We want to see a combination of the two. And that is not to downplay the importance of knowledge. It is not to downplay the importance of facts. Facts have an important role in the context of larger what we call big ideas and in the larger context of how we learn them and how we apply them.

Mr. MOLLOHAN. You do not want either/or.

Mr. PRATT. Exactly.

GOVERNMENT FUNDING

Mr. MOLLOHAN. Where is the—how to combine the two successfully? Where is the recommendation to policy makers on how to do that? Where is the recommendation that as members of Congress, or state legislators, or the executive branches at the federal and state levels, where is the how to? And, coming from the experts, if your policy makers would fashion your programs thusly and fund them at this rate, you would achieve this balance that would make science successful from kindergarten through twelfth grade.

Mr. PRATT. Let me start with two or three dimensions. Again, going back a little bit to my earlier statement about the comprehensive, systemic approach to it. I mean, there are several dimensions. One is starting with a standard. And if you look at the current national science education standards, as well as the benchmarks from AAAS, they address those outcomes, those goals. Unfortunately, very few schools, you know, address all four goals. And one of the reasons for that is the instructional materials, call it textbooks if you will, in many, many cases do not address that broad perspective on science education. The curriculum materials developed with NSF funding literally for the last thirty or forty years are well tuned to those four goals. They were not always expressed quite that way. But if you go back and examine those materials you will find them very supportive. That is the kind of professional development to support the use of those materials and that type of instruction and those broad based goals are what we, when we say professional development that is what we want to see in the training of teachers and principals, to go back to a previous question.

And assessment. One of the problems is the assessments. Part of it is because of the technology of assessment. And I mean our ability to write the items, our ability to, you know, to administer them. The ability to measure those somewhat less fact oriented parts of the equation are not well developed. But we need to develop better assessment items or abilities, tools I should say.

Mr. MOLLOHAN. See, when I hear what you are saying I hear you saying, "It is out there as a study. It is out there as a recommendation."

Mr. PRATT. We know how to do it. It is part of the research I alluded to earlier from NSF.

Mr. MOLLOHAN. And we know how to do it.

Mr. PRATT. We know how to do it.

Mr. MOLLOHAN. Well, let me ask the question this way. Is there any place out there where it is actually happening? A model, an example of a school system where they really have done what Mr. Nye said at the very beginning of his testimony, namely everything all at once. We are back to this. And then you went through almost defining the elements of what had to happen in order to do everything at once. I am back to that.

Mr. PRATT. All right.

Mr. MOLLOHAN. Where is it happening? I mean, I think it would be extremely instructional not only to, at the federal level, but down to the superintendent level if there were some consensus about how to and perhaps, and you are saying everybody has these recommendations. If there was some consensus which could perhaps be arrived at more at looking at where it has happened than hearing about it could happen.

Mr. PRATT. It is always risky to give examples. But I will cite some school districts, because I am reasonably familiar with some of the investigation of this. Not as thoroughly as I would like to be. And this is not necessarily exhaustive, so bear with——

Mr. MOLLOHAN. But do you agree we have to get down——

Mr. PRATT. Oh, yes.

Mr. MOLLOHAN [continuing]. To this in order to implement.

Mr. PRATT. I think if you looked, if you looked across the neighbor, so to speak, at two of your neighbors, Fairfax County in Virginia and Montgomery County in Maryland.

Mr. MOLLOHAN. Well Mr. Wolf looks at them pretty much all the time as he represents——

GRADE SCHOOL PROGRAMS

Mr. PRATT. You will find some very strong, excellent programs. At the elementary level, Pasadena, California; Gilbert, Arizona; El Centro, California in Southern California. A district that is, like, 80 percent under, you know, low economic level students, Title I students. Excellent, excellent leadership by a superintendent down there. They have brought science and literacy education into one and improved the scores not only in science but in literacy and mathematics by emphasizing elementary science. I mean, there are others I could cite. I could even go back to my home district of Jefferson County, Colorado and say you would find some excellent programs there, particularly in the elementary science, but K–12. So there are a number of those around.

One of the problems is that you can always find excellent, excellent schools. The challenge to school districts, to the educational community, is what we call scaling up. How do we really take it from a few highly qualified teachers using excellent materials under strong leadership with a principal, and scale that up, if you will, to every school district, I mean excuse me, every school and every student in the district. That is the challenge.

Mr. MOLLOHAN. That is a buy-in issue, is it not? I mean that is a, if you actually have the examples that are applicable in different circumstances, urban, rural, whatever the different circumstances you all would acknowledge or identify, that is a buy-in issue, is it not?

Mr. PRATT. Well, I am going to go back——

Mr. MOLLOHAN. In my, in my, excuse me, and just to get it down to where I can really relate to your answer. In my state, it would be getting it down to the county superintendent, really. And then, in turn, down to the principal. But it would also be, if we are going to do everything all at once, it would also be getting it into the education schools to teach teachers to be inspirational and also fact training. How do you do that?

Mr. PRATT. Well, as they say that is the $64,000 question.

Mr. MOLLOHAN. Well, that is the question really we are looking to have an answer to.

Mr. PRATT. You need leadership, to back again. But part of the problem with leadership, a leader has to be knowledgeable. And a leader has to have some experience. And what we know about buy-in is that it does not necessarily come up front, pre-implementation, pre-application. Buy-in comes from carefully thought out application of what we have just been talking about, if you will, the innovation, the quality materials, and a careful, shall we say, observation and evaluation of those, and seeing the success of those. That is where buy-in comes. It is when a school district or a principal says, "I am going to do this. I am going to support it. I am going to gauge what happens very carefully."

And when the success begins to happen, and it does not happen overnight. Another major flaw in our thinking often is it takes a matter of years. That is when buy-in comes.

Mr. MOLLOHAN. Mr. Nye.

LEADERSHIP IN COMMUNITY

Mr. NYE. May I ask a question of Mr. Pratt? Those school districts you mentioned, have studies been done about the environment? That is to say, about what goes on in that community? In Pasadena, for example, you have the Jet Propulsion Lab. And you have Cal Tech.

Mr. PRATT. More Cal Tech than Jet Propulsion Lab.

Mr. NYE. Well, the one is run by the other. Then in, what was another example, Montgomery County is the high tech corridor, there. Fairfax County, a lot of aerospace, and there is a lot of defense contractors. In the case of El Centro, there is a naval station there, right? And the couple times I have been to El Centro the Blue Angels are flying around all day. I am not kidding. And so I wonder if the people in the community who choose to go into the school system as administrators and teachers, they have to be influenced by the community that celebrates or embraces science and technology. So perhaps part of our overall strategy should be to make sure that every school district is somehow influenced or affected, by a high technology business. I know there is a lot of concern about earmarks, when I was a consultant to the Department of Justice on a military airplane as an engineer, I noticed that the pieces for the plane were being made all over the place. And there may be great value to that. There may be great value to giving communities a high tech business that affects the school district. And that has got to be, that has to be susceptible to analysis. Do we know, do we have information about that?

Mr. PRATT. I am not sure that question has been asked. But the question about leadership, both at the district level, superintendent and the curriculum office, as well as local principals. That has been studied fairly extensively. And so it is clear that leadership makes a significant difference. And I would, I could probably even cite names in each of these districts, both at the superintendent, if I, you know, thought about it well enough. At the superintendent level as well as the local, what we call the science coordinator level, the kind of job I had for most of my career. It is that level of leadership.

Now, sure they gain from the nature of the community. We all know that the community makes a difference. But there are enough exceptions in that list, El Centro being one of them. I do not think the naval base had much if anything to do with the success down there.

Mr. MOLLOHAN. Well it would be interesting if you would, for the record, submit a list of those, and perhaps, obviously, and perhaps that would be very instructive. And perhaps we could, you know, follow up and see what is happening in some of those communities.

We often hear when we talk about this, or talk with experts about this, of successes in community rich, or communities rich in technology activities, and people who work in those activities. That those communities, that there is a relationship between the quality of the math and science education. And that goes along with the recommendation that it is great to have scientists teaching science. I do not know what percentage of the country is so blessed, but lots of places in rural areas are not so blessed. So we have to overcome that challenge of having the expertise and that attitude in the community, and that value of science in the community and its education, and what it means imported perhaps, or substituted in these areas that are not in the way I am using this communities that are rich in technology activities.

MONEY FOR SCIENCE EDUCATION

Mr. NYE. Well, I think we have a real opportunity with the internet. If we make sure that rural schools, rural school districts, have very good electronic information systems, it certainly seems that we could export this at very reasonable cost. I mean, this should be, this should be a straightforward thing to do. There are people, I am sure, who are experts on how to distribute this information in an economical way.

Mr. MOLLOHAN. Yes. Let me point out that this Committee in the stimulus package includes in NTIA $4.7 billion for broadband expansion into the rural areas. Having provided that funding, it is another thing for those rural communities to take advantage of that. Because it is, that is, I wish it were a straight line. It is very difficult. But we are going to work that issue because we recognize how important that is.

Well, I am very interested in models or examples of where this balance has been achieved between what I am referencing as inquiry based and content rich class, and how you do that in different academic environments. Let me ask you, we fund NASA, NIST, and NOAA. All three of them have education programs. We fund those education programs here at the Committee. And they often go beyond the traditional classroom setting. We are trying to fund activities that seek out and prototype, if you will, these balances. And try to support programs that are taking powerful math and science into the classroom, and teaching teachers to teach in that environment. Do you have any comments about the role of these agencies, or any familiarity with the programs that these agencies are engaged in in promoting this? And words of support for those activities by these agencies and consequently our financially supporting them?

Mr. NYE. Well from personal experience——

Mr. MOLLOHAN. Opportunity to advertise, actually, here, and advocate.

Mr. NYE [continuing]. That is a lot of, that is a lot of what NASA does in its outreach, is talk about how great space exploration is. And to put it rhetorically, what is not to love about that? One of the most compelling moments of my life was when a man from NASA came to my elementary school in Washington, D.C. and dipped things in liquid oxygen. And then, thank goodness, he set them on fire. And it was spectacular. It was as though he were holding rockets in his hand. And I think the reason it made such an impression on me was he loved what he was doing. He was passionate about it. So if there are people in these organizations that are passionate.

My grandmother in order to pay the mortgage on her house took boarders, people who would rent rooms in her house. And one of them is a man who is still alive who worked for, at that time, the National Bureau of Standards. And he would take me upstairs and show me things through his microscope, astonishing things. Worlds I had never seen. And the reason that he was so influential on me is because he loved what he was doing. So if we, if we can declare that it is okay, or that it is a worthy pursuit of these government funded organizations that have roles to play in space exploration, weather monitoring, or climate monitoring, maintaining standards in scientific excellence around the world starting here, we provide those people the means to send people, send their people into the community in informal science. I think that is a, a very small cost with enormous dividends.

Mr. MOLLOHAN. These agency programs in education, Mr. Pratt?

Mr. PRATT. I have mixed feelings, mixed experience. That means good and bad, is what I mean by mixed. And the bad is not that they are low quality. The negative side, first, is that we have some very serious problems that you and other members of your Committee have alluded to. Or not alluded to, it has been specifically addressed. Whether it be poor cities, whether it be low economic, you know, areas, whether it be underrepresented students, it is the quality of science at the elementary level, the amount of science. We have some very serious education, science education problems in this country. And I do not think they are being squarely addressed by the—call them mission specific, or agency specific—programs. That is not to say, you know, we should not fund those and so I have to be very careful that I do not say that they are misdirected. I do not——

Mr. MOLLOHAN. We should make them better.

Mr. PRATT. But we should make them better, and we should find a way, it takes some effort. It involves a combination of educators and the scientists in NOAA and NASA and NIST, as well as NIH and others that are not under your purview.

Mr. MOLLOHAN. Well, let us start with your recommendation.

QUALITY OF TEACHERS

Mr. PRATT. Exactly. That is why I spoke about a mile wide and an inch deep. They are excellent programs but if you look carefully at them they may not, and usually do not, address specific standards. And they do not address the school districts, and the quality of teaching that we should address.

Mr. MOLLOHAN. Could you give us an example——

Mr. PRATT. I will give you one example.

Mr. MOLLOHAN [continuing]. Of what you mean and how it can be related to that? And how these programs could be so directed?

Mr. PRATT. Well, examples can get me into as much trouble as they can be of value.

Mr. MOLLOHAN. Well, this is your chance to help us.

Mr. PRATT. I know.

Mr. MOLLOHAN. So an example would be helpful.

Mr. PRATT. Two months ago I responded to an announcement that a group related to NASA and with NASA funding was going to present an all day Saturday workshop on the Kepler program, the Kepler mission, which of course, if all goes well, will launch tomorrow morning. I attended that session at the University of Colorado in some very nice space facilities there. There were three excellent presenters, workshop leaders, three of them. There were eighteen of us in attendance. We spent most of the day on some excellent activities which helped me much better understand some fundamental astronomy of solar, possible solar systems in the rest of the universe, and added a little bit of my knowledge of astronomy. But if I were a classroom teacher, I would have had, you know, a poster and a few ideas to take back to my classroom, but I do not think it would have done me anything fundamentally for the quality of my teaching, or my knowledge in this particular case in astronomy.

Now, I understand, and I got excited about, and I will watch the results of Kepler. And I understood a great deal about the criteria for the, how do you find a star that might possibly have an actual planet associated with it.

Mr. MOLLOHAN. I am not understanding your example. I mean, the population we are trying to target here is K–12 teachers. We——

Mr. PRATT. Now, I was not a teacher, of course, but the people in attendance were classroom teachers.

Mr. MOLLOHAN. I see, okay.

Mr. PRATT. Middle school, mostly middle school, well there was one elementary. Middle school and high school teachers.

Mr. MOLLOHAN. Give us an example of where it works well.

Mr. PRATT. The Explorer program where NASA has moved to. I mean, after many years, I think, of trying to determine its effectiveness and to some degree measuring its effectiveness, it is my understanding, having kind of watched and been a slight part of this——

Mr. MOLLOHAN. Is the Challenger——

Mr. PRATT. I have seen NASA take its money, much of its money, and say, we are going to sponsor, I do not know what the exact number is but one or two schools per state and systemically, systematically to use my terminology again, work with the staff of that school in order to improve the quality of science teaching in that school. Now, they will be using NASA personnel when available. They would be using some NASA materials. But it goes far beyond that. It addresses the broad issue of the quality of the teachers, the instructional materials, and possibly even the assessment in those schools.

Mr. MOLLOHAN. Well, that is very helpful. Thank you. Mr. Nye?

Mr. NYE. So Mr. Pratt, may I ask it this way? You are saying in the example of the Kepler mission, it took all day but it might not have been taught, and it promoted space exploration and it promoted NASA. But it might not have been tied to the science standards. Is that what you are saying?

Mr. PRATT. Well, more specifically not tied that closely to the needs of classroom teachers.

Mr. NYE. Yes.

Mr. MOLLOHAN. Okay, thank you.

Mr. NYE. So these very well intending people, but somehow coming from within the agency without being tied to the, maybe, national standards. They are not using the resources as effectively as we might.

Mr. MOLLOHAN. Like strategic planning, or relating to something?

Mr. NYE. But bear in mind, passionate people doing, they are enthusiastic about their business.

Mr. MOLLOHAN. Yes.

Mr. NYE. Right.

Mr. MOLLOHAN. There have been accounts in the press, and otherwise we hear of the lack of science and math college degrees among those teaching those subjects in primary and secondary schools. And then there is the idea that teaching, good teaching techniques, a teacher can teach anything. What is the current situation? And is there a growing trend for teachers to get degrees in the, majors in the fields that they are going to teach rather than majoring in education?

Mr. PRATT. Definitely. University education programs in many, many cases are becoming five year programs. So you assume, you start with a student with an undergraduate degree, in this case in science or mathematics, but not restricted to those. And then to some degree in their senior year, but mostly in a first year following, a first year of graduate school, they would do their education courses, do their practice teaching, possibly even do an internship in a local school district. So I cannot give you stats across the country but that is definitely the trend. You see some excellent examples. University of Texas has something called UTeach where they have a very strong program in that direction.

It is a trend, now. And remember that schools are filled with teachers who, you know, have been trained previously. So we have a long ways to go even though we may be, we may be improving the current state of undergraduate teacher education.

Mr. MOLLOHAN. I had a group of West Virginians, and they are in the educational community, visit me a couple of months ago with the, I want to get this right. With the notion that to the extent we are able to introduce IB courses into high schools we advance the number of youngsters who go into math and science. And I can see, obviously, that correlation is obvious. The issue of getting IB courses in schools that do not have them is another question. But first I want to ask, Newsweek's Challenge Index measures the percentage of seniors in a school taking AP and IB courses. What common practices and what common characteristics exist in schools with the highest percentage of participation in AP and IB schools?

Mr. PRATT. There are several things. Number one, you have to have a highly qualified staff.
Mr. MOLLOHAN. Yes.
Mr. PRATT. I mean——
Mr. MOLLOHAN. First and foremost, probably.
Mr. PRATT. Yes. To teach college level courses.
Mr. MOLLOHAN. And if you do not have that——
Mr. PRATT. That is right.
Mr. MOLLOHAN [continuing]. Forget it.
Mr. PRATT. And it also means facilities, to echo back to—
Mr. MOLLOHAN. Yes.
Mr. PRATT [continuing]. A previous concern.
Mr. MOLLOHAN. So when you are going around——
Mr. PRATT. You also have to have——
Mr. MOLLOHAN [continuing]. Trying to promote that——
Mr. PRATT. You also have to have quality science education at the previous grade levels so the students are prepared to take, so they can come into the high school or their latter two years prepared to take these courses. Those are the major ingredients. I think one other less tangible, and maybe not as well known, is that many schools are encouraging more students to take these courses without necessarily forcing them— well, what should I say? Without measuring the success of these courses by the number of students who get threes or fours and fives on the test, and therefore quality to be exempt of, in other words, encourage them to take advanced level courses, IB and AP being the best examples that are available to most school districts. But saying, we want you to take this course. We know you may not do quite as well as the very top students and so we do not want to preselect you because of any reason. You know, because of the nature of your previous education, and so on. So giving more students a chance to show what they can do by motivating them in these courses, even though they may not take the, they may not result in the fours and fives. So being a little careful about assessing the success of these programs by the number of students who really do test out of college courses. And saying this is a good experience for many of our students. I will not say all students. But a much broader audience of students than in the past.

Now they are, you also need to know that the nature of at least AP courses are being challenged by a number of folks. And the College Board is making some strides in improving the quality of the courses so that they become more than just content, to go back to our previous question, just content grinding courses. And that they become, that they have a broader set of goals for science education, or physics education, or biology education. So there is a bit of a backlash. Not so much about the fact that we should not have students taking advanced courses, but the nature of the course sometimes are so narrow.
Mr. MOLLOHAN. Well, that does not serve the intended purpose.
Mr. NYE. Well, it is once again, if you are not prepared in elementary school——
Mr. MOLLOHAN. Yes.
Mr. NYE [continuing]. You are not going to do well on the Advanced Placement test. And yet, a lot of people are taking the Ad-

vanced Placement test. There is peer pressure to take it, and there is pressure on the teacher to take it. But it is not clear that it really makes you an advanced student.

Mr. MOLLOHAN. Well, thank you all very much for appearing here today. I just think it has been an excellent hearing. And the information which we have had the benefit of your providing will be extremely helpful to the Committee. And perhaps as questions arise, specifically one thing or another, we can call on you all to give us direction. It has been a special hearing because of all the students that were here. So as we express appreciation to you I want to end on a student question to both of you, each respectively. And end on an inspiring note.

When and how did you first become inspired? Mr. Nye?

Mr. NYE. I do not remember. It was so long ago.

Mr. MOLLOHAN. That will be disappointing.

Mr. NYE. Let me say a couple things, though. First of all, in the room today is my older brother. And my older brother came out one day with a chemistry set, which as I recollect was a Gilbert which was made by the same company that makes Lionel Trains. Fabulous trains.

Mr. MOLLOHAN. I remember those.

Mr. NYE. Well there is still a whole, Mr. Chairman if you have extra income that you are trying to dispose of, the toy train industry will be more than happy to help you. With that said, he put two chemicals in my hand and made a third chemical. And it was the same chemical that I smelled when my mother cleaned the windows. Now, this was ammonia.

Mr. MOLLOHAN. Yes.

Mr. NYE. And this was like magic. But I realized even very, very young, before I had the use of very many words, I realized that he knew what was going to happen. That with this mixture he could predict the future. And that to me, that has compelled me my whole life. And I am almost sure it was the same summer I became fascinated with bees.

And then another moment that is unforgettable, I had a rubber band powered airplane, still made. I am not a stockholder or anything, but it is the Sky Streak made by Guillows. They are still made. And just if you are into this, it has no landing gear so it has much better thrust to weight ratio. And so I had inferred, watching fish, that if you were to bend the rudder of this aircraft it would turn. And not only would it turn, it would bank. That there was some coupling, as we say in math, between the roll and the yaw. And so I threw it. And I had lubricated it at my older brother's instruction. I lubricated the rubber band with soap, with dishwashing detergent. And the thing turned three times. And it came back to me like a boomerang. Just right to my hand, like in a cartoon. And I realized that you could make aircraft and steer them, and you could predict the future. And this, I guess, changed my life.

Mr. MOLLOHAN. That is a great answer. Mr. Pratt.

Mr. PRATT. I always want to be in science. I can remember a second grade textbook, textbook, it was not hands on science. A textbook that stirred me. I remember astronomy in the sixth grade, Bill, when I suddenly realized there was, I could think beyond the immediate both time and distance wise. I guess that is one of the stages you go through.

The real question that I will expand on, or modify your question, is why did I decide to teach? I went through undergraduate and had a major in chemistry and physics, one of the few people in the State of Oklahoma at that particular time. And I was all set to accept a job that was offered to me without even, without even an application at the R and D department at Phillips, Phillips Petroleum Company in Bartlesville, Oklahoma. And April of my senior year I was walking down the hall in the science building and the chemistry professor, my major professor, chemistry professor, came to me and he said, “Harold, how would you like to teach school next year?” And I said, “You have got to be kidding.” I said, “You have got to be kidding.” Why would I do that? And in Oklahoma that would be half the salary I would get as a chemist. And he said, “Well,” he said, “I just, you just seemed to be the kind of person that I think would be good in the classroom.” He said, “Why don’t you come talk to the superintendent?” So he took me down the hall and introduced me to the superintendent in a small school called Perry, Oklahoma. 300 kids in a high school. And for whatever reason, I decided to teach.

I got married and went, had to do something in the Army to fulfill my draft obligation. Came back and landed a job as a chemist making good money, soft money. I only worked from eight to five, and I went home, and I could do anything I wanted after five o’clock. And I had that job for almost two years. And I read one day, this was in 1959 to be precise. I read one day that the National Science Foundation, I hardly even knew who the National Science Foundation was, was going to fund teacher education through summer institutes in something called academic year institutes. And I said, “You know, if the NSF and therefore the government is that interested in the quality of science education.” I really, this was almost the way, the thought that went through. “If they are that interested in science education then, you know, I think I will go back into teaching.” And I did. And I found a job in Colorado, which is a little better than Oklahoma as far as pay and teaching conditions are concerned. And it was one of the best decisions I ever made. Because I took advantage of every opportunity the NSF provided, both me and my school district, to this very day. Because I have seen what that kind of money, that kind of support can do for individuals and can do for school districts.

Mr. MOLLOHAN. Well, thank you both for those inspiring answers and for your testimony here today. This Committee is privileged to have you appear, and we are benefitted by that testimony.

Mr. PRATT. Well, thank you for the opportunity.

Mr. MOLLOHAN. Thank you both.

Mr. NYE. May I say one more thing?

Mr. MOLLOHAN. Please.

Mr. NYE. Mr. Pratt really reminded me why I wanted to be the Science Guy. And this is serious. I was working at a company in Redmond, Washington, which is before Microsoft was in Redmond, Washington. And I was a young man. I was volunteering as a Big Brother, United Way Big Brother, and I was also volunteering at the Pacific Science Center which is, it is like a museum but a science center is traditionally a place where you can grab stuff. So it is a little different business plan. And I was working for people who were, or seemed to be, obsessed with making a profit every quarter. This was a big focus. And they were, I guess for no better word, they were terrified of anything made in Japan. Anything made in a Japanese company must be inherently better, must have better patent protection, must be less expensive, must be better for any customer. And then I got involved in a thing where they were charging some of my work, and my colleague's work, to the Space Shuttle program when it was not really associated with the Space Shuttle program. And so I decided that I was working at a place that was really focused on the past. They were focused on the wrongs that had been done to them and their entitlement rather than the future. So I quit, October 3, 1986, approximately. And decided to try to influence the future. And I will say by and large it is very, very rewarding to try to influence the future. And I thank you again for taking so much time with us this morning and this afternoon. Thank you.

Mr. MOLLOHAN. Well, thank you for influencing the future and for, in a very informed way, influencing the Subcommittee. Thank you both.

Mr. NYE. Thank you.

Mr. MOLLOHAN. The hearing is adjourned.

Questions for the Record for Harold Pratt

1. What role do professional respect and salary play in recruiting and retaining those with science and math degrees as K-12 teachers?

Professional respect and salary are two important factors among many when students consider teaching. A study in Wisconsin of 200 undergraduate STEM students tells us that low pay was a significant factor but that ability and interest factors, i.e working with kids or whether they would be good at teaching, was also important.

2. What efforts are being made to have students do science as a key element of their science classes along with learning fundamental content and reproducing standard experiments?

Better funded school districts are "doing science" very well. There are some well intentioned programs and state policies that call for specific amount of inquiry in the schools, but unfortunately, this not fully actualized in a lot of areas, especially in low income schools. There is a good deal of professional development for teachers to help them understand and teach inquiry and National Science Foundation programs which are helping support science investigations at the elementary level. But we need much better research and funding to help schools do a better job with this.

3. How well do state science standards that have resulted from No Child Left Behind cover the full range of science learning, including the ability to analyze data, reason scientifically, and conduct measurements, and are there assessment vehicles in place to cover more than science content?

All states have developed science standards, which largely reflect the national science education standards developed in 1996 by the National Research Council (NRC) and the American Association for the Advancement of Science (AAAS) Benchmarks for Science Literacy. However, many state Science standards contain far too many elements. The science curriculum is often so crowded that in far too many states students are not given enough time to really learn how to analyze data, to reason scientifically and to conduct measurements. In addition, although states have similar standards for science education, there are significant differences in when, how, and what students are expected to learn. Many state science standards are often not clear and most standards are simply not aligned with valid assessments. We must identify a clearly defined set of national core ideas in science that spell out to all stakeholders exactly what all students are expected to know and be able to do in science.

4. If the members of NSTA could have one wish to improve science education generally, what would it be?

Our wish would be more funding for professional development for all teachers of science, including elementary teachers.

5. The advent of college majors following the Civil War reflected the fact that knowledge had grown to the point where it was no longer possible to approach college education as an effort to become a renaissance person. Today, there is certainly more general science content that could be taught than there is time to teach and learn it. How do you see science education evolving to the knowledge explosion and the information age along with the Internet and the growing sophistication and complexity of computer games?

Obviously it is very important for science education and science educators to keep up with the huge amount of new knowledge and cutting edge technologies and much of this can be done with ongoing professional development provided to teachers.

Many teachers are also working to extend the typical learning environment and incorporate technologies that would make it seamless between what is taught in the classroom and what students encounter outside the classroom.

Keep in mind that science education is all about helping to develop students' critical thinking skills. When students are able to think critically, like a scientist, they can better understand, process and respond to the new knowledge around them.

6. Critical science issues such as climate change demand understanding that spans the traditional disciplines of physics, chemistry, and biology; how do students learn science in an interdisciplinary fashion while gaining a reasonable command of the traditional disciplines?

Many of the interdisciplinary issues can addressed within the basic disciplines when the content is closely related to the science of the issue. The solutions to most of the interdisciplinary issues require fundamental science content so background should be addressed with the basic science curriculum. This may require some adjustment or revision of the basic science courses. Some courses, especially in biology and chemistry, already have programs that teach fundamental science content through the use of community and environmental issues. In addition, many schools offer seminars and symposiums that cut across more than one discipline, such as science and social studies, so that the political and social issues can be integrated with the science in addressing critical issues.

7. Recruitment and retention of quality teachers is an issue. Improving salaries is often considered as the solution. However the "quality of a professional work life" may also be part of the solution. Countries with high TIMS and PISA scores often have teachers spending significantly less time in the classroom than their peers in the US. Time is built into their workday for teacher collaboration, planning, and professional development. Do you see this type of system fitting into U.S. science educational reform?

Absolutely. NSTA strongly urges every school to build structured collaborations of teachers who are given time during the school work week to focus on key issues of teaching and learning of science. With professional learning communities (PLCs) teachers can come together with one another and other stakeholders such as scientists and researchers at least once a week to review student work, new instruction, better ways to teach, and advances in science. Studies have shown that collaboration among teachers result in more innovative practices in teaching. More funding, more support from administrators to revise school schedules and allow teachers to work together, and more access to knowledge bases such as higher education are necessary before these reforms can take place.

8. It is often recommended that K-12 science teachers need to be teaching science using various best practices (inquiry, problem solving, etc), however, most teachers are teaching the way they were taught by their university science professors (i.e., lecture and content heavy). How do we break that cycle?

To break this cycle we first must change the culture in higher education, especially among presidents and administrators, so that education is valued as much as scientific research and publishing at our nation's colleges and universities. Scientists must focus more on their own teaching abilities, how students learn, how content is taught, and the technologies that impact student learning. It is important that we support and build much stronger collaborations between the faculty at colleges of education and faculty at the colleges of STEM to strengthen teacher education programs.

Sustained professional development must be provided to in-service teachers to change teaching behaviors that focus heavily on lecture and rote memorization.

9. What programs and/or school systems have you found that are currently effective in improving science literacy and achievement for school children?

There are a number of school districts that have implemented effective programs, usually with the support of the National Science Foundation via one of the Systemic Initiative (SI) in the late 1990s and early 2000s, or the Mathematics and Science Partnership Programs (MSP) in the years 2004-09 (for which documentation is available). Inverness Research Associates and other organizations have evaluated and reported on the success of these K-12 programs. The following synopsis of a few districts is a small sampling of what has been accomplished.

Gilbert Arizona

The Gilbert School District developed a district-wide elementary science program with the support of a Local Systemic Change (LSC) grant in 1999. During the next six years the district drew on the LSC model and other support from knowledgeable districts. In doing so, it evolved from a few lead teachers piloting new hands-on science kits into a fully implemented district-wide science program for grades K-6.

Denver Public Schools

The K-12 science education reform effort began in 2004 as a part of a major MSP program at University of Pittsburgh and University of Wisconsin Madison. Through extensive professional development of teachers at all levels K-12, coupled with the selection and purchase of inquiry-based textbooks and kits, the district restructured the curriculum and instruction in virtually every classroom in the district.

San Diego

The basis of support for the K-12 improvement efforts in the San Diego Unified School District came from an Urban Systemic Program (USP) funded by the NSF. Under the leadership of the district science coordinator, with strong support from the superintendent and from the partnership with the National Academy for Curriculum Leadership at BSCS, the district developed the capacity to identify, pilot, and implement new innovative instructional materials in all grade levels.

Seattle

The Seattle Partnership for Inquiry-Based Science was a district-based Local Systemic Change Project funded by the NSF between 1996 and 2002. The project, which was guided by the National Science Education Standards, provided a kit-based program for each grade level K-5 and provided extensive professional development for all teachers --approximately 100 hours of training per teacher over five years. A variety of other supporting elements, such as community *partnerships, parent events, and a materials center, were put in place to strengthen and to institutionalize the project.*

Portland

Through five years of work the USP in Portland Public Schools developed an "improvement structure" for mathematics and science education. It did this by developing a well respected and experienced leadership team -- a district-wide group of math and science teachers committed to math and science improvement and a cadre of classroom teachers with vastly improved skills and knowledge in math and science teaching as well as the skills and knowledge about how to work together to continuously improve high quality programs and deliver and maintain curricular materials.

Student Questions

1. **How do you justify funding NASA and space exploration during a war and economic bust? Why should that still be a priority?**

The National Science Teachers Association takes no position on funding for NASA and/or space exploration. We would like to see increased funding for NASA education programs however.

2. **Who is your role model and why?**

My role model was my high school science teacher.

3. **Do you believe in aliens?**

No

4. **I just graduated from high school last year and was lucky enough to have the opportunity to participate in a 3-year research program. This program encouraged me to pursue science policy – much like the content of this committee. Mr. Nye and Mr. Pratt, where do you stand on research education, its funding, and do either of you anticipate that it could help create the "passion" discussed so much in this hearing?**

Education research is absolutely critical for a number of reasons. First, research gives us information on how the brain works and how students learn. Valuable research funded by the National Science Foundation over the past two decades has shown us new ways to effectively teach science, new curriculum, and new learning tools. Funding for education research should remain strong so that these innovations can continue. But we also must work harder to get education research to classroom teachers in a format that they can understand and use it effectively so that we can help all students achieve.

5. **Most specialized funding in science focuses on students who are behind. Do you think this should remain the focus or should funding go towards students who are interested in advanced learning?**

The National Science Teachers Association mission is to "promote excellence and innovation in science teaching and learning for all." We believe that adequate funding should be provided so that all students, regardless of achievement levels, are provided a world-class science education.

6. **When and how did you first become "inspired"**

I was first inspired very early on while watching the stars and planets, then later on during an elementary science class while we were doing some experiments.

7. **Our teachers are very passionate about science, but what can you do about most all of our principals and administrators who don't get it? I think that's why many teachers don't stay in the profession.**

I agree completely, many school administrators don't understand what it takes to provide a quality science education. Lack of administrative support is a big reason that many science teachers leave the profession. For this to change we need not only teachers but also parents, business leaders, and the science community to really speak out to principals, superintendents and school boards and then work together on the reforms needed to ensure students are getting a quality science education.

8. **"Burdensome standards" were mentioned. What good is a standard if it does not create a burden for a student to meet it?**

Students should be challenged in their classes to meet and exceed their state science standards. When I referred to "burdensome standards" I was referring to the current patchwork system of 50 states with 50 sets of burdensome standards.

Many of these state standards are not always sufficiently clear and specific to provide useful learning objectives for instruction and assessment. Too many standards result in curricula covering too many topics in too little time. In addition, the lack of coherent standards often leads to a fragmented curriculum that fails to build knowledge and skills from year to year. To address this challenge NSTA is leading an effort called Science Anchors, which will bring greater focus, clarity, and coherence to science education. Science Anchors will serve as a model for K–12 science education standards that draws from current national standards documents (Benchmarks for Science Literacy and National Science Education Standards) but would be more streamlined and focused than the current documents. Content in the science disciplines would be organized around a small number of big ideas that develop over the K–12 span, and crosscutting concepts and skills that would unite the disciplines in a deep, meaningful way. Attention would be given to the number of concepts and skills students would be expected to acquire each year so learning goals are realistic for students and manageable by teachers.

THURSDAY, MARCH 5, 2009.

WHERE ARE WE TODAY: TODAY'S ASSESSMENT OF "THE GATHERING STORM"

WITNESS

NORMAN R. AUGUSTINE, FORMER CHAIRMAN AND CEO, LOCKHEED MARTIN

OPENING STATEMENT BY CHAIRMAN MOLLOHAN

Mr. MOLLOHAN. The hearing will come to order. Mr. Wolf is tied up in a meeting right now. He will be here momentarily, but he has asked that we go ahead. So we will do that by welcoming our distinguished witness today, Mr. Norm Augustine. Welcome back.

Mr. AUGUSTINE. Thank you.

Mr. MOLLOHAN. It is a pleasure to have you back as a witness before this Subcommittee. This week we have been taking testimony on the state of science in the United States, and roles of four research agencies in our jurisdiction, NASA, NSF, NOAA, and NIST, in the overall science enterprise. This morning we gained insight into K through 12 science education and science teacher preparation.

Following the issuance of the "Rising Above the Gathering Storm" report there has been a bipartisan effort to double the fiscal year 2006 funding of NSF, NIST, and the Department of Energy Office of Science over ten years. The report recommended 10 percent per year increases for these agencies. The stimulus funding provided in the American Recovery and Reinvestment Act of 2009 increased fiscal year 2009 funding for NSF by roughly 50 percent and for NIST by almost 70 percent, while NASA science received a boost of about 8 percent, and NOAA received about 20 percent of its annual total.

In two of our earlier hearings we have heard of the important contributions of NASA and NOAA to the overall science enterprise, particularly in the physical and Earth sciences. Balancing funding for these four agencies is a major element of our Subcommittee responsibilities. Now we want to check on how well federal funding and policy are addressing the recommendations contained in the "Rising Above the Gathering Storm" report, and to hear from the principal author of the report. Welcome, Mr. Augustine.

Your written testimony will be made part of the record, and I see that you are prepared to make oral comments. So if you will proceed, and welcome again.

Mr. AUGUSTINE. Well, thank you, Mr. Chairman, and thank you for this opportunity to appear. I should correct the record. I suspect that you gave me more credit than I deserve. There were twenty of us that worked on " The Gathering Storm" report. I was one of those twenty, although I did of course chair it.

The status of "The Gathering Storm" report is the subject of some complexity because of the number and the variety of recommendations that were made. You and the Committee, I am sure, are well aware that the report was requested by a bipartisan group from both the House and the Senate. There were, as I have noted, twenty of us on the Committee that performed the report for the National Academies of Science and Engineering and the Institute of Medicine. The committee included university presidents, CEOs, former presidential appointees, several Nobel Laureates, K through 12 educators, and so on. I am proud to say that two of our members are now serving in the President's cabinet.

If this hearing were to have taken place just two months ago, I could have easily answered the question of what has happened since " The Gathering Storm" report was written. I could have reported to you that a new graduate university has been founded with an opening day endowment that equals that which took MIT 142 years to build. I could have reported that 200,000 students were studying abroad, mostly on government funding, mostly in science and technology. Or that a short term 25 percent increase in R and D funding is underway. Or that a program was underway to make the country a nanotechnology hub, a global nanotechnology hub. Or that an additional $10 billion was being allocated to K through 12 education, or an additional $3 billion to the current effort on research.

If I had done that I would have had to tell you that those actions were being taken by Saudi Arabia, China, the U.K., India, Brazil, and Russia, respectively.

In the U.S. during that same period of time one of our national labs putting its research staff and other staff on a mandatory two day a month unpaid furloughs. Another one of our national labs began laying people off altogether. Our nation's contribution to the international program in nuclear fusion was reduced to what was called by DOE a "survival mode". Industry continued to spend three times as much on litigation as it did on research. And I would suspect many would be scientists and engineers, young people, were reconsidering their career plans.

Fortunately your hearing is today and not two months ago. The stimulus legislation, I believe, will have an enormous positive impact in the areas of research, science, and education. I would like in the time that has been allotted to me to quickly summarize the two most recent status reports that have come out with regard to these two key areas, one being education and one being science, innovation and engineering as a package.

The one that refers to education is the PISA report. I can never remember what that stands for but it is Programme in International Studies in something. They conduct standardized examinations at several grade levels in thirty different countries. The results were released about three months ago. The Washington Post described them as showing that we were stagnating in science. But there was one bright spot, which was fourth grade mathematics. Putting aside the fact that not many corporations hire fourth graders, there is another significant issue here if one does a little mathematics of their own. My calculations show that if we continue to "jump forward", to use the Post's words, at the pace we have the last ten years, we will catch up, for example, with Hong Kong in just eighty-five more years, assuming they do not get any better. Clearly we are on a path that is not going to be adequate in terms of educating our people in math and science.

The second study was conducted by the Information Technology and Innovation Foundation. Its results were just released. They studied forty countries and have dropped the U.S. to sixth place in its innovation capabilities. But more importantly, when they looked at the last decade and ranked Nations according to the progress made during that decade, the U.S. ranked fortieth, dead last.

I would like as a final comment to make a personal suggestion, not part of " The Gathering Storm" report. It stems from the fact that there are about 15,000 independent, with emphasis on "independent", school districts in this country. As I have traveled around some of those schools, both in this country and in many other countries, I have been struck by the fact that there are some truly bright spots. Here and there you find people who are really doing things right. It would seem to me that it would be helpful to take some of the suggestions that have been posed and to disseminate them broadly so that they could be replicated. To do so I think it would be useful if the Congress and the President were to appoint a commission, involving educators, but not headed by an educator, to survey what are best practices? What are those bright spots in the U.S. and abroad? What are their ingredients, how can we replicate them? And what are the common features that they have? This is something that each individual district cannot reasonably do. But they could certainly benefit from it.

Mr. Chairman, that concludes what I had to say in my opening remarks. I would be happy to take questions.

[Written testimony of Norman R. Augustine follows:]

The "Gathering Storm:" Three Years Later

Statement of

Norman R. Augustine
Retired Chairman and Chief Executive Officer
Lockheed Martin Corporation

and

Chair, Committee on Prospering in the Global Economy of the 21st Century
Committee on Science, Engineering, and Public Policy
Division on Policy and Global Affairs
The National Academies:
National Academy of Sciences, National Academy of Engineering,
Institute of Medicine

Before the

Subcommittee on Commerce, Justice and Science
Committee on Appropriations
U.S. House of Representatives

March 5, 2009
Washington, DC

Mr. Chairman and members of the Committee:

Thank you for this opportunity to appear before you to discuss what has taken place since the national Academies first released the document which has come to be known as the "Gathering Storm" report, after the first line in its title. It was my privilege to appear before your committee previously to provide a "One Year Later" update as to the impact of that report; hence, my comments today are in effect a "*Three* Years Later" update.

The National Academies—the Academy of Science, the Academy of Engineering and the Institute of Medicine—trace their origins to the establishment of the National Academy of Science by President Lincoln and the Congress with the objective of providing independent advice to the nation and its leaders on matters within the Academies' fields of expertise. The Gathering Storm committee was created by the Academies in response to a bipartisan request by members of both the House of Representatives and the Senate. Our committee consisted of twenty members including university presidents, corporate CEO's, Nobel Laureates, K-12 educators and former Presidential appointees. We are proud that two of our members are now serving in President Obama's Cabinet.

As you are aware, the overall findings of the Gathering Storm committee were given strong bipartisan support in both the House and Senate and by President Bush and now by President Obama. I suppose I could report that much was accomplished during the first two years after the Gathering Storm report was published. A new research university was established with an opening day endowment equal to MIT's after 142 years. Each year, over 200,000 students studied abroad, mostly pursing science or engineering degrees, often under government-provided scholarships. Government investment in R&D began a 25 percent increase. An initiative was funded to make the country a global nanotechnology hub. An additional $10 billion was budgeted for K-12 education, with emphasis on math and science. And a $3 billion add-on to the nation's research budget was announced.

These actions took place in Saudi Arabia, China, the United Kingdom, India, Brazil, and Russia, respectively.

What about the United States? After Congress overwhelmingly authorized many of *The Gathering Storm's* recommendations, the needed funds to implement them were not appropriated. As a result, one leading national laboratory began to impose mandatory two-day-per-month "unpaid holidays" on its science staff; several laboratories began laying off researchers, the U.S. portion of the international program to develop plentiful energy through nuclear fusion was reduced to "survival mode," America's firms continued to spend three times more on litigation than research; and many young would-be scientists presumably began reconsidering their careers. Fortunately, some of these adverse consequences were later curtailed by budgetary actions in the Supplemental Legislation, but few steps forward were taken.

Were today's hearing to have taken place two months ago I am afraid that what I have just reported would have been the essence of what I had to say—although it should be noted that a number of states have initiated "Gathering Storm efforts" of their own—albeit at a much smaller scale than is ultimately going to be needed at the national level.

With the recent passage of the stimulus package the so-called "shovel ready" rebuilding of the nation's physical infrastructure was accompanied by funding to begin the repair of a number of structural problems in our nation's economy—most notably in education and scientific research. While the National Academies has not, to the best of my knowledge, undertaken any specific studies of the impact of the near-term investments in the nation's physical infrastructure, the investments in science and education generally reflect Gathering Storm proposals and, properly executed, can be expected to have a very positive and lasting effect.

But three major challenges still remain insofar as the Gathering Storm recommendations are concerned. First, if the nation's K-12 education system is to be repaired and our basic research program is to be productive, *sustained* funding will be required—not simply a one-time injection. In fact, were the latter to be the case, the result might even prove to be counterproductive. Second, the shortage of K-12 science and mathematics teachers with primary degrees in the fields they teach remains to be adequately addressed. And third, the nation's science and engineering cadre and its education community must now produce results that justify the funds which are being entrusted to them.

It is perhaps appropriate at this point to note why the Gathering Storm committee placed such great emphasis on science and engineering, including the related endeavors of research and education. The reason is that while scientists and engineers comprise only four percent of the nation's workforce, they disproportionately create jobs for the other 96 percent...and *jobs* for all citizens is what the Academies report was really about. Numerous other studies have shown that over the last half-century between 50 and 85 percent of the growth in the Gross Domestic Product is attributable to advancements in science and engineering. In the current century, the Knowledge Century, this effect is likely to be even more prominent.

Other witnesses have, I understand, been requested to provide an assessment of the health of our nation's science and engineering enterprise. In this regard I would simply note that it was the unanimous view of the members of the national Academies Gathering Storm committee that the United States is perilously close to falling decisively behind other nations in key areas of science and engineering.. U.S. industry, generally reluctantly, has found a means of avoiding the consequences of such a trend; namely, establishing its research centers *outside* the United States. It is to be expected that engineering, prototyping, pre-production and production activities—and the jobs that accompany them—will then follow this pattern unless specific actions are taken to the contrary.

In closing I believe it is appropriate to take note of what are perhaps the two most recent studies bearing on America's evolving position with regard to the key ingredients of 21st century competitiveness: education and innovation. With respect to the former, America of course has some outstanding schools, teachers, administrators, and students—but overall, by global standards, we are failing our children...and failing them abysmally. In international tests in math and science, U.S. students invariably rank near the very bottom of the global class. *The Washington Post* summarized the results of the most recent 30-nation International Program for Student Assessment, observing that achievement in science is essentially stagnating, but that there is one bright spot: fourth grade math—where America "jumped" ahead. Unfortunately, most firms do not hire fourth graders, but were the media a bit more adept at math itself it would have calculated that at our rate of "jumping ahead" we will catch up with the students of Hong Kong in a mere 85 years...assuming, of course, that the children of Hong Kong don't get any better in the meantime.

Turning to innovation, the Information Technology and Innovation Foundation just released its most recent assessment of innovation and competitiveness in which it dropped the U.S. to sixth place among the 40 nations considered in its assessment. As if to punctuate the observation, it concluded that in terms of progress over the most recent decade, America is in last place.

In summary, the recent legislative steps affecting the funding of science and education are very constructive indeed...but as I have noted, much remains to be accomplished. When it comes to competitiveness for 21st century jobs, we are engaged not in a spring but in an endurance race.

Thank you for permitting me to appear before you today.

NORMAN R. AUGUSTINE was raised in Colorado and attended Princeton University where he graduated with a BSE in Aeronautical Engineering, magna cum laude, and an MSE. He was elected to Phi Beta Kappa, Tau Beta Pi and Sigma Xi.

In 1958 he joined the Douglas Aircraft Company in California where he worked as a Research Engineer, Program Manager and Chief Engineer. Beginning in 1965, he served in the Office of the Secretary of Defense as Assistant Director of Defense Research and Engineering. He joined LTV Missiles and Space Company in 1970, serving as Vice President, Advanced Programs and Marketing. In 1973 he returned to the government as Assistant Secretary of the Army and in 1975 became Under Secretary of the Army, and later Acting Secretary of the Army. Joining Martin Marietta Corporation in 1977 as Vice President of Technical Operations, he was elected as CEO in 1987 and chairman in 1988, having previously been President and COO. He served as president of Lockheed Martin Corporation upon the formation of that company in 1995, and became CEO later that year. He retired as chairman and CEO of Lockheed Martin in August 1997, at which time he became a Lecturer with the Rank of Professor on the faculty of Princeton University where he served until July 1999.

Mr. Augustine was Chairman and Principal Officer of the American Red Cross for nine years, Chairman of the National Academy of Engineering, President and Chairman of the Association of the United States Army, Chairman of the Aerospace Industries Association, and Chairman of the Defense Science Board. He is a former President of the American Institute of Aeronautics and Astronautics and the Boy Scouts of America. He is a current or former member of the Board of Directors of ConocoPhillips, Black & Decker, Proctor & Gamble and Lockheed Martin, and was a member of the Board of Trustees of Colonial Williamsburg. He is a Regent of the University System of Maryland, Trustee Emeritus of Johns Hopkins and a former member of the Board of Trustees of Princeton and MIT. He is a member of the Advisory Board to the Department of Homeland Security, was a member of the Hart/Rudman Commission on National Security, and has served for 16 years on the President's Council of Advisors on Science and Technology. He is a member of the American Philosophical Society and the Council on Foreign Affairs, and is a Fellow of the National Academy of Arts and Sciences and the Explorers Club.

Mr. Augustine has been presented the National Medal of Technology by the President of the United States and received the Joint Chiefs of Staff Distinguished Public Service Award. He has five times received the Department of Defense's highest civilian decoration, the Distinguished Service Medal. He is co-author of *The Defense Revolution* and *Shakespeare In Charge* and author of *Augustine's Laws* and *Augustine's Travels*. He holds 23 honorary degrees and was selected by Who's Who in America and the Library of Congress as one of "Fifty Great Americans" on the occasion of Who's Who's fiftieth anniversary. He has traveled in over 100 countries and stood on both the North and South Poles of the earth.
(Rev: July 2008)

NATIONAL ACADEMIES "GATHERING STORM" COMMITTEE BIOGRAPHIC INFORMATION*

NORMAN R. AUGUSTINE [NAE*] (Chair) is the retired chairman and CEO of the Lockheed Martin Corporation. He serves on the President's Council of Advisors on Science and Technology and has served as undersecretary of the Army. He is a recipient of the National Medal of Technology.

CRAIG BARRETT [NAE] is chairman of the Board of the Intel Corporation.

GAIL CASSELL [IOM*] is vice president for scientific affairs and a Distinguished Lilly Research Scholar for Infectious Diseases at Eli Lilly and Company.

STEVEN CHU [NAS*] is the director of the E.O. Lawrence Berkeley National Laboratory. He was a cowinner of the Nobel prize in physics in 1997.

ROBERT GATES is the president of Texas A&M University and served as Director of Central Intelligence.

NANCY GRASMICK is the Maryland state superintendent of schools.

CHARLES HOLLIDAY JR. [NAE] is chairman of the Board and CEO of DuPont.

SHIRLEY ANN JACKSON [NAE] is president of Rensselaer Polytechnic Institute. She is the immediate past president of the American Association for the Advancement of Science and was chairman of the US Nuclear Regulatory Commission.

ANITA K. JONES [NAE] is the Lawrence R. Quarles Professor of Engineering and Applied Science at the University of Virginia. She served as director of defense research and engineering at the US Department of Defense and was vice-chair of the National Science Board.

JOSHUA LEDERBERG [NAS/IOM] is the Sackler Foundation Scholar at Rockefeller University in New York. He was a cowinner of the Nobel prize in physiology or medicine in 1958.

RICHARD LEVIN is president of Yale University and the Frederick William Beinecke Professor of Economics.

C. D. (DAN) MOTE JR. [NAE] is president of the University of Maryland and the Glenn L. Martin Institute Professor of Engineering.

CHERRY MURRAY [NAS/NAE] is the deputy director for science and technology at Lawrence Livermore National Laboratory. She was formerly the senior vice president at Bell Labs, Lucent Technologies.

PETER O'DONNELL JR. is president of the O'Donnell Foundation of Dallas, a private foundation that develops and funds model programs designed to strengthen engineering and science education and research.

LEE R. RAYMOND [NAE] is the chairman of the Board and CEO of Exxon Mobil Corporation.

ROBERT C. RICHARDSON [NAS] is the F. R. Newman Professor of Physics and the vice provost for research at Cornell University. He was a cowinner of the Nobel prize in physics in 1996.

P. ROY VAGELOS [NAS/IOM] is the retired chairman and CEO of Merck & Co., Inc.

CHARLES M. VEST [NAE] is president emeritus of MIT and a professor of mechanical engineering. He serves on the President's Council of Advisors on Science and Technology and is the immediate past chair of the Association of American Universities.

GEORGE M. WHITESIDES [NAS/NAE] is the Woodford L. & Ann A. Flowers University Professor at Harvard University. He has served as an adviser for the National Science Foundation and the Defense Advanced Research Projects Agency.

RICHARD N. ZARE [NAS] is the Marguerite Blake Wilbur Professor of Natural Science at Stanford University. He was chair of the National Science Board from 1996 to 1998.

GATHERING STORM RECOMMENDATIONS

Science

- Increase federal investment in research by 10 percent per year over the next seven years, with primary attention devoted to the physical sciences, engineering, mathematics, and information sciences—without *dis*investing in the biological sciences.
- Provide research grants to early career researchers
- Institute a National Coordination Office for Research Infrastructure to oversee the investment of an additional $500M per year for five years for advanced research facilities and equipment.
- Allocate at least 8% of the existing budgets of federal research agencies to discretionary funding under the control of local laboratory directors.
- Create of an Advanced Research Projects Agency—Energy (ARPA-E), modeled after DARPA in the Department of Defense, reporting to the Department of Energy Undersecretary for Science. The purpose of this entity would be to support the conduct of long-term "out-of-the-box," transformational, generic, energy research by universities, industry and government laboratories.

Education

- Establish 25,000 competitive science, mathematics, engineering, and technology undergraduate scholarships and 5,000 graduate fellowships in areas of national need for US citizens pursuing study at US universities.
- Establish a Presidential *Innovation* Award to recognize and stimulate scientific and engineering advances in the national interest.
- Provide a federal tax credit to employers to encourage their support of continuing education.
- Provide a one-year automatic visa extension to international students who receive a science or engineering doctorate at a U.S. university and meet normal security requirements, and providing automatic work permits and expedited residence status if these students are offered employment in the US.
- Institute a skill-based, preferential immigration option
- Reform the current system of "deemed exports" so that international students and researchers have access to necessary non-classified information or research equipment while studying and working in the US.

VIEWS ON COMPETITIVENESS

- "We're standing pat while the rest of the world is passing us by. If we continue on this path, our chances of being the leader in the knowledge economy in the decades to come are between slim and none."
  William E. Kirwan – Chancellor, University System of Maryland

- Writing about attending graduation at Rensselaer: "The foreign names kept coming—'Hong Lu, Ku Xie, Tao Yuan, Fu Tang'—I thought the entire class of doctoral students in physics were going to be Chinese, until 'Paul Shane Morrow' saved the day…my complaint…was that there wasn't someone from the Immigration and Naturalization Service (there) stapling green cards to the diplomas of each of the foreign-born PhDs."
  Thomas L. Friedman – Author, "The World Is Flat…"

- "If the U.S. doesn't get its act together, DuPont is going to go to the countries that do."
  Chad Holliday – CEO, DuPont

- "If companies were run like many (K-12) education systems, they wouldn't last a week."
  Thomas Donohue – President, U.S. Chamber of Commerce

- "We're well on our way to becoming America, the land of the free and the home of the unemployed."
  Norman R. Augustine – Retired Chairman & CEO, Lockheed Martin Corp.

- "When I compare our high schools to what I see when I'm traveling abroad, I'm terrified for our workforce of tomorrow."
  Bill Gates – Founder, Microsoft Corp.

- "If you don't solve (the K-12 education problem), nothing else is going to matter all that much."
  Alan Greenspan – Chairman, Federal Reserve

- "We go where the smart people are. Now our business operations are two-thirds in the U.S. and one-third overseas. But that ratio will flip over (in) the next ten years."
  Howard High – Spokesperson, Intel Corp.

- "We had more sports exercise majors graduate than electrical engineering grads last year. If you want to be the massage capital of the world you're well on the way."
  Jeffrey R. Immelt – Chairman, CEO, General Electric
  (Speaking in Washington, DC)

- "Where nations once measured their strength by the size of their armies and arsenals, in the world of the future knowledge will matter most."
  Bill Clinton – President of the United States

- "We as a country have chosen not to compete…we've killed investment banking and now we are killing engineering…it's our future and we are throwing it down the drain."
  Craig Barrett –CEO, Intel Corp.

- "…in today's integrated and digitized global market, where knowledge and innovation tools are so widely distributed…: Whatever can be done, will be done. The only question is will it be done by you or to you."
  Thomas L. Friedman – Author, "The World Is Flat…"

- "It's not just that kids need to go to school, they need to learn in school."
  Emiliana Vegas – World Bank

- "Where is Sputnik when we need it?"
  Bill Gates – Founder, Microsoft Corp.

- "Will America lead…and reap the rewards? Or will we surrender that advantage to other countries with clearer vision?"
  Susan Hockfield – President, MIT

- "…our present crisis is not just a financial meltdown crying out for a cash injection. We are in much deeper trouble. In fact, we as a country have become General Motors—as a result of our national drift. Look in the mirror: G.M. is us."
  Thomas L. Friedman – Author, "The World Is Flat…"

- (The way to move forward is) "through science, science, science, and science, with science and technology to rebuild our infrastructure, make it green and reduce our dependence on foreign oil, to use science for innovation, to grow our economy, creating good paying jobs, educating people to be competitive, science to make America healthy, and science to preserve the planet by stopping global warming, and science to protect the American people."
  Nancy Pelosi – Speaker of the House of Representatives

- "If we spend one trillion dollars on a stimulus and just get better highways and bridges—and not a new Google, Apple, Intel or Microsoft—your kids will thank you for making it so much easier for them to commute to the unemployment office … "
  Thomas L. Friedman – Author, "The World Is Flat…"

- "The future of our nation and people depends not on just how well we educate our children generally, but on how well we educate them in mathematics and science specifically."
  Senator John Glenn

- "Technology has been paying the bills in this country…we're killing the goose that laid the golden eggs."
  Stan Williams, Senior Fellow, HP

- "It must gall them to see bright, aspiring scientists starved of funding while Detroit gets rewarded for its stupidity."
  Daniel Lyons, Newsweek

- "Providing short-term rescue packages to the economy without simultaneously fixing its fundamental problems, such as education and investment in research, is like feeding a candy bar to a diabetic."
  Norman R. Augustine, Chairman, National Academies Competitiveness Study

- "Every day, our economy gets sicker—and the time for a remedy that puts Americans back to work, jump-starts our economy and invests in lasting growth is now."
  Barack Obama, President of the United States

Mr. MOLLOHAN. Well, what was the bright spot?

Mr. AUGUSTINE. The bright spot was fourth grade arithmetic, where we improved.

Mr. MOLLOHAN. And is that by way of emphasizing all of the unbright spots?

Mr. AUGUSTINE. I think that is what the media was doing, yes.

SCIENCE AND EDUCATION

Mr. MOLLOHAN. Well, that is a bright spot because that is the grade that some of the witnesses have identified as the point where interest in science and math drops off unless it is strategically nurtured from that point forward. So at least we have a good point, or a trending toward a good point, to pick up and to think about.

Well let me ask you if there are any bright spots with regard to NSF and maybe NIST, and the Department of Energy Office of Science, those three agencies that were targeted for doubling. And I think we, just recently with the stimulus package, assisted in that goal. Are you able to comment specifically on the trend lines in those agencies? And are there any positive signs coming out of that?

NATIONAL SCIENCE FOUNDATION

Mr. AUGUSTINE. I think there are. I think, for example, that NSF is truly a national asset. The things that make NSF particularly strong, in my judgment, include the fact that a good part of its staff comes in for a few years, contributes, then leaves—and then a refreshed staff comes in. I think it is particularly important at NSF that they rely heavily upon peer review for their grants. I have been amazed at NSF's ability to tackle a diversity of challenges. You may recall, Mr. Chairman, some years ago, I guess eight or nine years ago, I chaired the Commission on Antarctica, where it was decided to build a new station at South Pole, this is an incredibly difficult logistics undertaking . . . sort of the last thing I would expect an organization of scientists to be good at. And they did, in my judgment, a marvelous job. I think there are many bright spots, both in terms of management capability and in terms of NSF's use of funds.

I think that other agencies also have their bright spots as well. One of the brightest is a potential one at DOE, ARPA–E, which of course your bill has funded, and I think will fill an important need if it is properly implemented. The latter is important. We learned a lot of lessons with ARPA and what made it, or DARPA, what made it successful. Hopefully we can apply those same lessons at ARPA–E. I believe Secretary Chu is well qualified to do just that.

I think you mentioned NIST. Of course, NIST is renowned for its expertise in the specific areas with which it deals.

Perhaps I should mention at this point that the National Academy study sought to find a centerpiece to bring together the various recommendations it made. We wanted to find a centerpiece that permeated the many issues that affect our country. A centerpiece was extremely important; a centerpiece that resided in the area of principle concern. In our view, that was the physical sciences, engineering and mathematics . . . Just as, for example, the Manhattan Project in World War II, or the Apollo project after

Sputnik. We chose energy as our centerpiece. In so doing it was not that we thought the NIH or NASA or the DOD or NIST were less important. It was just that they did not happen to directly fit our particular centerpiece. So we just did not talk much at all about them. I should emphasize that point.

THE GATHERING STORM REPORT

Mr. MOLLOHAN. Well, talk about that a little more. Dr. Cicerone when we asked him why NASA science and NOAA science were not included in " The Gathering Storm" report, his notion of it, without going into any detail, was that the report was of high quality but quickly done and felt that perhaps those accounts just were not looked at. Is that the case? Or tell us why science in those agencies was not addressed?

Mr. AUGUSTINE. I think that is certainly part of the explanation. I hesitated to mention that factor because it sounds like an excuse, sitting where I sit today and having had responsibility for "The Gathering Storm" report.

Mr. MOLLOHAN. Well, I do not want you to misunderstand. Believe me, Dr. Cicerone had nothing but praise for " The Gathering Storm" report. But he was just thinking that, maybe that was the direction understood to go, and in the time frame that is the direction you went.

Mr. AUGUSTINE. Yes. We found ourselves with ninety days to do the report.

Mr. MOLLOHAN. Yes, and that is the point.

Mr. AUGUSTINE. Which frankly we welcomed because we all had other things we had to do in life. Also, we thought that if you cannot get ideas in ninety days you are not likely to get them in 900 days.

Mr. MOLLOHAN. Yes.

Mr. AUGUSTINE. So we were very comfortable with that notion. The available time was certainly a factor. We did not have time to fill out the entire pattern. But in my mind the more significant thing was that we tried to pick a centerpiece, we picked energy. DOD, and to some extent NIST and NOAA and NASA, although having some connection, it is nowhere near as direct as NSF and DOE.

SCIENCE ISSUES AT AGENCIES

Mr. MOLLOHAN. Well, let us talk about science, if we might, just in these agencies. The stimulus package does give them a shot in the arm, so to speak. And for those that are the subject of your report, I think the stimulus pretty well put them back on a ten-year track where they were before. Is that enough? I mean, are we doing in NSF and NIST what should be the baseline upon which we consider future increases? There have been some who have indicated you need to be careful with that. You need to be careful it is not ramping up too quickly, and they cite NIH. That ramping up too quickly creates instability in the, and ups and downs cause problems that ripple through those programs. So we are looking for balance. And if you cannot do it in specific numbers or percentages, maybe you can talk to the issue of balance generally. And if you can talk with us specifically, that would be great in regard to NSF and NIST, and indeed the Department of Energy, although we do not fund it.

Mr. AUGUSTINE. It is an important issue. We compared the investment in this country with investments in other countries in science using many different measures. Unfortunately many of these are input measures, although we also looked at a few output measures. The input measures we looked at included percentage of the GDP, which is a particularly important measure because it gives an indication of what you have to support, how big the train is that this engine has to pull. Investment per individual, per capita; investment in absolute terms. We looked at trends within this country of spending. The conclusion we arrived at was that for at least five years it would be appropriate to spend at the maximum rate at which we could spend efficiently. At the end of five years, stop, take a look at what we got for our investment. Also look ahead and see what others have done and what the requirements might be.

So the question boiled down to, "what can you spend efficiently?" This is not without controversy. But as we looked at our academic system, including the number of researchers available in key areas, the facilities available, and most importantly, the overall ability to efficiently absorb and manage fund increases. There is certainly some level that there will be waste. We saw the NIH's efforts had taken five years. That is about 14, 13 percent increase a year. So we proposed 7 years, which is about 10 percent a year. That looked to us to be an appropriate round number. It may be eight, it may be twelve, I candidly would not know. But it is like 10 percent.

Mr. MOLLOHAN. I see.

Mr. AUGUSTINE. We felt that amount could be efficiently spent. We said, set out for seven years, but spend at the maximum rate that you could efficiently spend at, then stop and take stock of where we are.

Mr. MOLLOHAN. So we are a couple of years from that point, although we are continuously taking stock of that.

Mr. AUGUSTINE. Yes. Obviously you would need to be assessing each year how things are going. But we are several years away from any assessment because during the first two years we did not accomplish much—to be very candid.

Mr. MOLLOHAN. After the hearing started Mr. Aderholt was the first person in the room. Mr. Aderholt.

Mr. ADERHOLT. Yeah, I just stepped out. Go ahead and recognize——

Mr. MOLLOHAN. Okay. Mr. Honda.

Mr. HONDA. Thank you, Mr. Chairman. Welcome back.

Mr. AUGUSTINE. Thank you.

SCIENCE EDUCATION

Mr. HONDA. You know, the last time you were here we were discussing the issues that were brought out by your work on " Above the Gathering Storm." And in your written testimony here, this is the third year post-report. A couple of years ago you said that there was no changes that were evident in the outcomes of student achievement between " Gathering Storm" and " Nation at Risk." And so that started me to think. But at that meeting I also asked you a question about innovation relative to education, and here in your concluding paragraph you said there are a couple of things that the two most recent studies bearing on America's evolving position with regard to key ingredients of the 21st century, competitiveness, education, and innovation. Now I asked you the question, how difficult would it be to teach innovation? You and the other person that was with you sort of said, " Well, it is pretty difficult because it is something that is innate in folks." Do you still hold that opinion?

Mr. AUGUSTINE. I still hold that opinion. It is difficult to teach innovation, Mr. Honda. But I think that an environment can be created where students could learn it. And I believe one can promote that learning, which I guess is called teaching. But in terms of just laying down a set of rules, which I have actually tried to do, that you should follow is inadequate. Innovation requires more than that. I think it requires experience. It also requires an educational curriculum that permits creativity. For example, I have visited schools in both Singapore and the People's Republic of China. They too are concerned that their educational systems, which by most measures are as fine as you can get. They are concerned that they do not provide for innovation, for initiative, for creativity. And they are trying to do something about it.

Mr. HONDA. Right.

Mr. AUGUSTINE. When you try to promote innovation it means proposing challenges to a person that they have to meet. It means permitting them to fail occasionally, and not to have the punishment for failure be inordinate.

Mr. HONDA. Okay.

Mr. AUGUSTINE. It has to encourage people to take risks.

Mr. HONDA. Okay.

Mr. AUGUSTINE. To think out of the box.

Mr. HONDA. Okay.

Mr. AUGUSTINE. And, when someone comes up with an idea that is contrary to the accepted belief, if they are roundly criticized for that they are not likely to be very good innovators. It takes a nurturing environment.

Mr. HONDA. But you just introduced about five or six teachable kinds of behavior, and that you can create an environment so that you can observe this creativity. And it seems to me that when I visit the high tech offices in IBM and Lockheed Martin, and you look on the walls you have all your engineers that have an expression of all the number of patents that they have. Most of them have one or two. Some do not have any. But every once in a while you have spikes. Now, one would conclude that they must be pretty creative, thoughtful, innovative. And it would seem to me that one could talk to them and ask them questions and sort of elicit the kinds of insights they may have, and then take this and convert that into, maybe I should not say instruction material, but, incorporate that into instruction so the youngsters will be encouraged to be creative. It is like asking youngsters, so what will the world be like if your eyeballs were at the end of your fingertips? How would things change? And my students would say, well, I cannot pick my nose or I will not be able to see. Or I could wait for girls and just do this around the corner. But that is another way of thinking.

So for a person like yourself it seems to me that one would sort of look for other people that would help us go through this initiative looking at innovation, and then find ways to do that. Because if innovation is key to competitiveness, and you can recognize it, it seems to me we should be able to distill it into discrete kinds of environments or behavior that can be replicated in the classroom so that we can have youngsters practice it. We say we want critical thinkers. How do we know we have critical thinkers? It is the way they think and they ask questions. And so I would ask that you, you know, sort of cogitate that again because I think that this is one of the key things that we need to look at in order to, you know, close that gap that we are all looking at.

My last question, Mr. Chairman, would be this. How would you define the term equity in the context of public education? And what would it look like for each child? If we are assessing youngsters with assessment tools, and then we are judging whether they are successful or failures, if we do not do it right in the beginning with a child then are we not determining whether the system has failed, that we failed them, rather than anything else? And where does rigor play in this when we compare ourselves to other countries?

Mr. AUGUSTINE. You always ask very difficult questions.

Mr. HONDA. But I do not have that much chance to talk to you.

Mr. AUGUSTINE. Regarding the question of equity, I have not thought a great deal about that, to be candid. If I were on the spur of the moment to try to define what would be equity, it probably would be something like being certain that we have a system that affords every child the opportunity to maximize their ability to contribute.

Mr. HONDA. Sure.

Mr. AUGUSTINE. Unfortunately, we do not do that today in a lot of areas.

Mr. HONDA. Is there a reason why?

Mr. AUGUSTINE. I think there are many reasons. Many of them come down to economics. I am a Regent of the University System of Maryland. I spent a lot of time recently with regard to the broad issue you raise. American universities lose about half their students along the way. A good part of those are because there is a chasm between what it takes in this country to get a high school diploma and what it takes to succeed as a college freshman, particularly in science, engineering, and math. The youth may have that diploma, but they are ill prepared to take on college work because of poor quality K through 12 education. That is one big problem.

The other large problem is a financial one, that a lot of our students have to drop out for financial reasons even though they are performing fairly well. Also, holding jobs part time makes it even more challenging to perform well academically. I think those are all ingredients to the issue.

If I might, I would like to come back to your question about innovation. Ironically, I think we are very good at innovation in this country. I think it is one of our strong suits, particularly in our universities, where critical thinking is the coin of the realm. It is not only welcomed but it is encouraged. In the company I had the privilege of leading, when I was there I think I had about 80,000 scientists and engineers working for me, I would be very confident that 1 percent of them got 90 percent of the patents for us. As you say, there are those spikes. We have to find the people who can produce those spikes and give them the opportunity to create. In science, the same people write the articles over and over. The same people come up with the new ideas. Those people are the treasures that will keep the rest of us employed.

Mr. MOLLOHAN. Thank you, Mr. Honda. Ranking Member Mr. Wolf.

Mr. WOLF. I thank you, Mr. Chairman, Mr. Augustine, welcome. I apologize. I have been apologizing to the witness. Governor Baliles was in my office and we were working on a project, and I just could not leave. And I wanted to be here.

One, I want to thank you for what you did on the Gathering Storm. If there was any bright spot, that was the—that was the only bright spot. I quickly went through your testimony. And it looks like you are really not that optimistic. Is that a fair statement, or do we want to just summarize what I think I know, what I may not know?

Mr. AUGUSTINE. I think, Mr. Wolf, I would characterize——

Mr. WOLF. Are we doing better, or even, or worse than you thought—hope we would do?

Mr. AUGUSTINE. The question is what we are doing better, even, or worse?

Mr. WOLF. Yeah, compared to when you did the Gathering Storm——

Mr. AUGUSTINE. The Gathering Storm——

Mr. WOLF [continuing]. The great report. Now where are we?

Mr. AUGUSTINE. I think I would say that with regard to the stimulus legislation, one robin does not make a spring even though it is a fairly—a robin on steroids, I guess you would say. Or maybe you wouldn't say that here! But my belief is that you have taken an immensely important first step. I am much more optimistic than I was two months ago.

I think we have continued to lose ground over the last three years relative to our competitors abroad. I think that one of the challenges is that we didn't get ourselves into this predicament overnight. Unfortunately, we won't get out of it overnight.

As the Chairman points out, we are talking about influencing fourth graders that 15 years from now will have a Ph.D in science. If what we do is put a big spike in the system and don't follow it up, I don't mean we have to have a spike every year, but we need to follow it up. If we don't, I think we will make many things worse, because if we put a lot of money into research and don't have researchers, that money will either go abroad or it will be wasted. Follow up is critical.

But, Mr. Wolf, I am always optimistic. I am much more optimistic than I was two months ago. But I still think that we are in a very vulnerable and exposed position.

Mr. WOLF. Well, I don't know that—you know, I don't think I am that optimistic. Is there a reporter here from the "New York Times"? Is the reporter here from the "Washington Post"? Is the reporter here from the "Wall Street Journal"? Is the reporter here from the "Chicago Tribune"? I mean, it is just not being covered.

Also I think part of the problem is that giants—you are one of the few giants that have really kind of left. The giants have left the field. I can't really think of many giants in the business community anymore. And when they speak really carry such tremendous weight. I think you do. There are still a number, but not to the degree that it used to be.

And the concern that I have, and we are trying to do something about it, is the country is broke. We are absolutely broke. We have run out of money. And Jim Cooper and I, Congressman Cooper, a Democrat, we have a bill in. We can't get it out of this institution. This is the most political, partisan institution. I have served for 28 years that I have ever been in. I mean, it is very, very. And so each side is looking to how they can make the point against the other side.

And so we have a commission that puts every spending program on the table, Medicare and Medicaid, Social Security, and tax policy, and does it in a way that say we don't do that so we can have a tsunami in the country. But if we do do it, we can have a renaissance in this country. We can create more jobs, put more money into math, and science, and physics, and chemistry, and biology, and cancer research, and research on autism, and research on Alzheimer's, and just kind of to change America.

And we are having a hard time moving it. We have the support. David Broder supports it. David Brooks supports it. David Walker supports it, Pete Peterson. But we can't get it out of this place. We just can't get it out.

They are not having enough problem in China. I mean, they are moving ahead and doing things. So I don't know that I am as encouraged that you would be. My wife and I, we have five kids and we have 13 grandkids. We are going to have another one. We just got a call two nights ago. I think that is going to be a very bleak situation unless some fairly dramatic thing is done.

So, one, I would hope you would speak out for our commission with Walker, and with Peterson. And Business Roundtable supports it, NFIB supports it, the Concord Coalition supports it, Senator Rudman, Republican/Democrat, totally bipartisan. We can make sure we have the resources to kind of focus and put it in here for the future for these young people that are here. That is the first thing.

Secondly, the staff said that you recommended that we should have a commission or an advisory group that goes around and looks at some of the best things that have been done.

Working with the Chairman, you know, we will work with you. I think I am going to offer that amendment here. I am going to offer that in the markup, or however the Chairman wants me to do it, or on the floor. And I think you should give us some ideas. Should this be a fast—a six-month turnaround? I mean, I don't think we have to have a two-year commission. And so we can look at some of the best things. There are a lot of good things going on at Thomas Jefferson High School in Northern Virginia. A lot of good things going on around the country.

If you could give us how you think it should be crafted, I will offer that amendment. You tell me what you think the necessary resources should be. If you tell me who you think should, not names, but types of people that should serve on it, I will offer that. And we will call it the " Augustine Commission to Bright Sunshine One" rather than " Gathering Storm One."

So we will try to do that. I will do it whether it passes or not, we will find out. I am also going to send you the material that we have on our—on our commission to get—to get control where we are, so we do have those resources.

I mentioned the other day, I forget what witness, two months ago I was on the train. I took the train from Washington to New York City. Have you ever done that?

Mr. AUGUSTINE. Many, many, many times.

Mr. WOLF. The next time you do it, don't read your book and don't read the paper. You can sit on either side of the train. And look at the factories. They are closed.

Mr. AUGUSTINE. I have observed that.

Mr. WOLF. Graffiti is on the side of the wall, MS13 graffiti. The windows are broken. The weeds are growing. In fact, some of the weeds are growing out of the windows. And you come through my old neighborhood. I am from southwest Philadelphia and South Philly. You go right through my old neighborhood. There was the largest General Electric factory I think in the world was there. It was GE switch gears. It is gone. You go back to my old neighborhood, the stores are boarded up. The factories have been broken into by drug dealers. You know, they don't make anything. And there is that bridge, the sign on the bridge, up in Trenton.

Mr. AUGUSTINE. "Trenton Makes, The World Takes."

Mr. WOLF. Yeah. What does Trenton make anymore? It should say the world makes and Trenton takes. And so we want to do this commission similar to yours. But we want to mandate that Congress has to vote on whatever the recommendations are.

I mean, I think if we could have had Gathering Storm with base closing commission language that would have required that Congress to vote up or down. Then it will force, because, you know, a lot of the people in this business, they love to give the speeches in the Rotary. They love to say, you know, America's best days are yet ahead. And the sun has barely begun to rise. And yet on some of these things that will make America's best days ahead for my grandkids and your grandkids, we are not kind of—we are just not kind of doing it.

So I want to thank you for your effort, too. We will offer that if you can be in touch with my office. I think you would have a fashion.

And the last question is I would ask you, as I have asked others, how do you think we are comparing to doing in comparison today? And interesting, every member of the Chinese bureau is an engineer, every single one. How do you think we are doing in comparison? If this were a footrace, a race which we are in, a race of a wonderful country—my grandparents came here from another country, a wonderful country that has had great opportunities. That has probably put in 80 percent of the food into Darfur. That is doing amazing things to help people around the world, in competition with a country, China, that has Catholic bishops in jail and plundering Tibet.

How do you think we are doing in comparison to what I call—as Ronald Reagan gave that speech, the " Evil Empire," as I call a very evil government. How are we doing, America our country, in comparison to China today?

Mr. AUGUSTINE. To use your footrace analogy, we had the good fortune in this country of starting out years ago with about a 20-yard lead in the 100-yard dash. It is probably more of a marathon now. But we started out with a good lead, and we have been gradually consuming that lead.

Today, I think we are still very much in the race. But we are losing ground rapidly. I don't think we are yet at the tipping point, but I think we are getting close. By tipping point, I mean to where it is very difficult, if not impossible, to turn things around.

I think that your comments about bipartisanship, or nonpartisanship, or whatever, if there is anything in the world we should be able to agree upon, it is educating our children and creating jobs for our people and not just scientists and engineers, but for everyone. Maybe that is the reason we have been able to keep this process, this particular issue, fairly nonpartisan.

Probably there are many in this room besides myself for whom education made all the difference in their lives. I was the first in my family to go to college. I was the second to attend high school. But there was a chance to go to college. Many people paid my way whom I have never met. That totally changed my life, and hopefully any contributions I might have been able to make along the way.

We must pay attention to education and creating jobs through science—that is where jobs get created today. Fifty to eighty-five percent of the GDP growth is attributed to advancements in science and engineering. That is why I think those fields are important.

And, Mr. Wolf, I would be honored to work with you on putting some meat on the suggestion that I made to create a commission. I think it is a six-month commission.

Mr. WOLF. Will you serve on it?

Mr. AUGUSTINE. I am not looking for a job, but yes.

Mr. WOLF. Oh, yeah. Well, it is not going to be a——

Mr. AUGUSTINE. Yes.

Mr. WOLF. Okay, good.

Mr. AUGUSTINE. Yes.

Mr. WOLF. We will drop it in and keep you——

Mr. AUGUSTINE. Two stipulations, sir. One is that I not be paid and the other is that I don't have to fill out all 10,000 forms you have to fill out whenever you do anything for the government.

Mr. WOLF. Okay. We will be in touch and work with you.

Mr. AUGUSTINE. The effort will take about six months.

Mr. WOLF. And thanks for your—thanks for your——

Mr. AUGUSTINE. Thanks for your kind words.

Mr. MOLLOHAN. Mr. Aderholt.

Mr. ADERHOLT. Thank you, Mr. Chairman. Thank you for being here today. You talked about the major challenges that still remain. And one of the things that you mentioned in your opening remarks and in your written statement that was provided is that the one-time injection of funding would actually be counter-productive. Now, obviously, I mean, you can—there is a lot of obvious reasons why that would be the case.

What is some other—I mean, just—I would like for you to just talk a little bit about that. When you put that into your statement what you were thinking and what your thoughts are. Like I said, it is obvious that that would be the case. Just expand on that a little bit.

MAJOR CONCERNS

Mr. AUGUSTINE. I would be happy to do that. I think there are two major concerns. The first is that we don't have the capacity to spend the money; that we encourage a lot of young people to study science and math and become researchers, and when they are done with their education there is no money to fund research. Research in this country is going to have to be funded largely by the federal government.

Industry has all but withdrawn from the research endeavor, basic research, because of the pressures of the marketplace, the near term, "what did you do last quarter?" We see the demise of great research institutions like Bell Labs, or the shrinking of Xerox research, or Dupont, or many great research facilities.

Government is going to have to pick up more of the load. Given those circumstances, the question gets to be what the government is going to be able to afford to sustain. And there is an additional problem with the so-called one-time stimulus. And that is the fact that there is a limit on how much one can efficiently spend; how much one can manage.

When you are dealing with long-term problems like education, like research, they have time constants of 10 or 15 years, whereas the Congress' time constant tends to be one or two years. In business it's one quarter. So what do you do with those long-term issues? I think that you just have to be prepared to sustain whatever it is you start.

I think that big injections that aren't followed up probably will be wasteful.

Mr. ADERHOLT. When you were discussing with Congressman Wolf about your optimism and various other things, a couple of times you mentioned that over the last two months you have been encouraged, immensely encouraged. I just was curious about that. What in the last two months has taken place and is giving you encouragement?

EDUCATION

Mr. AUGUSTINE. I think the commitment of the Congress and the President to putting substantial funds in the stimulus package for science and education, in a non-trivial amount, is very encouraging. But I wish it had been more, frankly. I think education didn't get the emphasis that I would like to have seen it receive.

I am afraid the way much of the education money is going to be spent would not have been the way the Gathering Storm Committee would have proposed. That is not entirely the case, but much of it I think is that way.

So my encouragement is really attributed to one thing, and that is the commitment of the President and the Congress to doing something about this problem. If that could be sustained, I think we can turn this situation around. I don't think we are anywhere near hopeless . . . yet.

Mr. ADERHOLT. But, of course, with the stimulus package to a large extent it is a one-shot thing.

Mr. AUGUSTINE. Yes.

Mr. ADERHOLT. But you are still encouraged even with that.

Mr. AUGUSTINE. I am. I think it is a great first step. I think what we need to do now is make research and education a part of the regular budget process and make sure we follow up. It has to be institutionalized.

Mr. ADERHOLT. Thank you, Mr. Chairman. Thank you.

Mr. MOLLOHAN. Mr. Serrano.

Mr. SERRANO. I am going to ask you the same question that I asked this morning.

You were laughing at the microphone, or am I asking the same question I asked this morning?

Mr. HONDA. Not just ready.

DIVERSITY IN EDUCATION

Mr. SERRANO. We always speak in this country a lot about diversity. But diversity does not mean, in my opinion and the opinion of most, not just making sure everybody gets a fair break, but inviting certain members of certain communities to participate in areas they usually don't participate in.

So for instance, when you look at numbers, statistics, you find out that 12 percent of the population is African-American and 15 percent, roughly, is Hispanic. And yet eight percent of people getting degrees in math and science are from these communities.

Other than the general approach to have more people participate in these kinds of endeavors, should we, should the Congress, should business, should the Administration be doing anything special to invite young people to consider this area?

Mr. AUGUSTINE. I am glad you asked that. I think we have an overall problem in this country where in the midst of this period of burgeoning science and technology, we are graduating 20 percent fewer engineers than we did 20 years ago. We are graduating 32 percent fewer U.S. citizens with engineering and science Ph.D.s than we did ten years ago. And part of——

Mr. SERRANO. Excuse me, when you say "fewer U.S. citizens," is that because we are graduating folks that are here from other countries?

Mr. AUGUSTINE. We are graduating 32 percent fewer U.S. citizens with Ph.D.s in math, science, and engineering from U.S. universities. Within that subset, there is an even more dismal situation. About 20 percent of the engineering degrees—I happen to be an engineer, so I am more familiar with that, go to women. The percentage that I have seen for African-Americans and Hispanics is more like six percent or so, which is vastly disproportionate to their numbers in our society.

If we are going to compete with other countries that have populations four times the size of ours, where a great preponderance of the people that go to college and study math, science, and engineering, we can't afford to handicap ourselves by not having half of our population on the playing field.

Not to consume too much of the time you have for your question, it has been mentioned that we lose these people, the people who could be great scientists and engineers, by the time they are in fourth grade. One of the problems, maybe not a problem but a challenge, is that science, engineering, and mathematics involve a very hierarchal learning process. It is heavily dependent on mathematics. If you didn't take algebra, you can't study trigonometry. If you didn't have trigonometry, you can't take calculus. You can't just jump in and say I am going to take complex variables and skip the rest. That is quite different from what it takes to go to law school, or medical school, or many other professions.

This decision point is very early in life. Unless we can interest women, African-Americans and Hispanics to get over that critical fourth grade point, they will probably have forgone the opportunity to ever become science engineers, or mathematicians.

I am not positive of the following numbers, but they are close. If you take 1,000 children in this country in first grade, by fourth grade 650 of them will be considered to be non-proficient in math. Now, once you fall behind in math you usually don't catch back up. A few do, but not many. If you go to eighth grade, it is 290 are left out of the original cohort of 1,000. If you examine 12th grade, it is 170—of which, happily, about 150 start college in a technical field. About half of these drop out of the field before they get their degree. So you wind up with just a small part of what you start with.

To your point, Mr. Serrano, we have to find a way to interest young children, particularly Hispanics, African-Americans, and women in engineering, math, and science.

My experience dealing with young people is that there are two things that really turn them on. That is dinosaurs and space. We are short on dinosaurs, but we have science. Somehow we beat that out of children fairly early on.

Mr. SERRANO. And I appreciate your answer, especially coming from you, because this morning we had a great hearing where we heard from scientists and a person representing teachers who teach science. But it is always the business community, where you come from, that says you are not preparing people.

So your message, in my opinion, resonates well, because it is a message that, as it gets included in the Chairman's reports from these hearings, is basically telling the educational system you have got to prepare more people for me. And you are not preparing the people for me.

And you are leaving out, in answer to my question, a certain segment of the community. And you are right, you can't—you know, it is what I used to say years ago. And I am not the only one who said it. You know, you help somebody along with a special college program or dollars in their pockets so they can go to school, you are going to get that back a million times, if you are only looking at dollars, once they start to work. You are going to get it back the first year most likely, or the second year, the third year, whatever.

And so I appreciate your answer. I thank you for your testimony today, for your being with us today. And like I said, I especially appreciate it, because as a former CEO of such a prestigious corporation, your words have to be heard, because it is your part of society that is saying send us people that can do the work. And as long as no one is left out, then it makes a lot of sense, so I thank you for that.

Mr. AUGUSTINE. Thank you.

Mr. MOLLOHAN. Thank you, Mr. Serrano.

Mr. Augustine, I was pursing a line of questioning. And I wanted to get to your thinking about extending the doubling recommendation for NSF and NIST and the Department of Energy Office of Science. What do you think about extending that to NASA Science?

Mr. AUGUSTINE. I should——

SCIENCE AT AGENCIES

Mr. MOLLOHAN. Let me ask you first of all, is there anything intrinsically different about science done at NASA than science done at NSF, or NIST, or Energy?

Mr. AUGUSTINE. I suspect there may be some differences, but I don't think any of them are terribly profound. One of the curious things about science is that one never knows where the applications will be. You may be doing something at NASA that has an important application at NIH and vice versa.

The NSF properly puts a great deal of emphasis on work done by others. NASA tends to do more in house. But I don't think there is any huge difference intrinsically.

Mr. MOLLOHAN. Okay. We have had witnesses earlier in the week, Dr. Cicerone and Dr. Fisk, former Associate Administrator of NASA for Science. Not surprising that he would support the doubling of the NASA science budget, but he did. And Dr. Cicerone expressed sympathy too.

So let me ask you first what do you think about the notion of putting NASA science on the same track that NSF, and NIST, and Department of Energy Office of Science are on, that is doubling within the seven-year period?

Mr. AUGUSTINE. As you noted, the Gathering Storm Committee really did not consider that. But my personal view would be that even not having looked at it in the detail we looked at the ones we did cover as recommendation, it would be a very appropriate thing to do.

Although it is not one of your Committee's responsibilities, we didn't mention the Department of Defense, which when I was a young engineer, was a primary source of funding for science. In my career, NASA provided much of the generic information and knowledge that we needed in the corporate world. NASA had always had its technical notes and technical reports. There was a library where you could go if you wanted to know something NASA was your source of information. Actually it was called NACA then.

I am not able to present a very factual case. My intuitive feeling is that money efficiently invested in science and education on talented people is probably about as highly leveraged as any investment I can think of.

Mr. MOLLOHAN. Were those references, your NASA references, you are testifying about, were they coming from NASA science or from aeronautics?

Mr. AUGUSTINE. It was aeronautics in those days.

Mr. MOLLOHAN. Well, comment on the NASA funding in aeronautics, in the aeronautics accounts, if you will.

Mr. AUGUSTINE. NASA's funding of aeronautics has over the years been neglected. NASA used to provide the basic knowledge that you needed in this country to design airplanes. Today that is being left largely to the companies that are involved. NASA still does important work in aeronautics, but as we all know, NASA has shifted a great deal of its attention to space over the years. And while I am certainly not opposed to that, I think it is unfortunate that aeronautics has been neglected to the degree it has.

Mr. MOLLOHAN. Is it more than unfortunate? Does it have competitiveness consequences? You know, at some point we really are going to get down to funding these accounts. And aeronautics has been neglected. Everybody has been concerned about that. Ranking Member Wolf, when he was Chairman, routinely increased funding for aeronautics as it came from the President's request for reasons that we would like you to elaborate on.

Mr. AUGUSTINE. The spending that has been neglected for NASA in aeronautics has important competitiveness consequence.

Mr. MOLLOHAN. Still today?

Mr. AUGUSTINE. Still today. It is a cumulative consequence. When one builds a new airplane, one draws upon what has been learned over the years. Today, corporate America is having to do more and more of that work on its own. As you will recall, it wasn't too many years ago we had four companies building large commercial jet aircraft. Today we have one. And, arguably, it is not the most prominent one on the planet any more. In that arena, NASA could help a lot.

There also is a military consequence. The DOD is historically very reluctant to invest in research. Were it not for the Secretary there today, we wouldn't have seen the increase we did see last year. And so as we reduce spending at NASA on aeronautical research, it impacts national security as well as commercial competitiveness.

Mr. MOLLOHAN. So NASA aeronautics research basically looks at fundamental research that industry doesn't do or isn't doing? What is lost here? Why shouldn't the private sector pick up its own research? And what is lost? What has been lost?

Mr. AUGUSTINE. I think that the——

Mr. MOLLOHAN. Why, because NASA isn't doing in aeronautics what it did previously?

Mr. AUGUSTINE. One of the characteristics of research is that the benefits often do not accrue to the entity that performed the research or the investor that paid for the research.

In the arena we have been discussing, the books I used if I wanted to know the lift and drag characteristics of a wing, for example, NASA (NACA) had whole books with different kinds of wings. You could find a wing that had the properties you were seeking. It was kind of a catalog. You could look it up, as the saying goes.

Now, one thing industry could do if it could afford to, would be for each company to produce its version of that book. But it would be a terribly inefficient way for us to compete with other nations and each other. First of all, the companies couldn't afford to do it. But even if they could, they would run two or three cases for wings to see what looked good for their immediate interest. The rest of the options would never be cataloged or looked at. It is this fundamental knowledge that NASA could bring.

Mr. MOLLOHAN. NASA is not doing that now?

Mr. AUGUSTINE. To a much lesser degree. And I use that only as an example. Today there——

Mr. MOLLOHAN. Yes.

Mr. AUGUSTINE [continuing]. Are of course alternatives. You have computer programs that address many issues.

AERONAUTICAL RESEARCH

Mr. MOLLOHAN. Is that kind of aeronautical research being treated differently around the world? Are countries around the world for their industry doing disproportionate basic research in aeronautics that we are not doing?

Mr. AUGUSTINE. I think it comes back to the model, the way our country is operated. In China, the government basically performs aeronautical research. In Russia, the country basically performs aeronautical research. In Europe, in my judgement, the companies are heavily subsidized through Airbus. Airbus, if I am not mistaken, initially went 25 or 30 years without making a profit. There are very few companies in this country that can do that. It was kept afloat by their governments. Airbus has built quality products. There is no question about that. The question is the appropriate role of government.

Mr. MOLLOHAN. Let me get back to my line of questioning. You commented on NASA science and recommending that it included in those agencies that the science research should have doubled funding within that seven-year period.

What about research efforts at NOAA?

Mr. AUGUSTINE. I think much the same arguments apply, whether it is NOAA, or NIST, or NIH, each for different reasons, perhaps. But as we all know, NOAA performs a terribly important function. They probably have saved tens of thousands of lives over the years through the weather forecasting they have made possible. NOAA is very dependent upon basic research.

Not having looked at NOAA specifically, my answer would be that increased research funding at NOAA is a very good investment up to the point at which one can no longer efficiently spend that money, either because of limitations on facilities, management skill, or the availability of researchers.

Mr. MOLLOHAN. Did Gathering Storm make judgments about what our competitiveness position would be if we were to commit to this doubling track? In other words, would we be where we should be with our foreign competition if we were to follow that directive?

Mr. AUGUSTINE. I must confess that our assessment was largely judgmental. And the reason for that was in part, time. But perhaps more importantly, we don't know what others are going to invest in the next five years.

If we look at the trends in China, if they could maintain that trend, which I doubt that they can now, we are obviously struggling to maintain our position. I think if we had implemented the Gathering Storm recommendations, we could have stayed ahead of China for a longer time. But China is, I think, going to have to be spending less money in this arena as well. That may help us.

Mr. MOLLOHAN. Would it be a fair summary of your testimony to say that you are recommending that the Gathering Storm recommendation, with regard to NSF, NIST, and the Department of Energy Office of Science, be made applicable to NASA science and to NOAA research, NASA research and science and NOAA research and science, that they be included in that doubling recommendation, number one?

Mr. AUGUSTINE. That would be my personal view. The one caveat is to be certain that the money could be spent efficiently.

Mr. MOLLOHAN. Right. And that is a word that either Dr. Cicerone or Dr. Fisk, I can't remember, using. I hear your testimony suggesting that at some point, I think you said maybe five years and maybe today is the right time, to reset, to look at and see how that recommendation relates to the real world, to how it impacts our competitive position vis-a-vis our foreign partners. Do I hear you recommending that?

Mr. AUGUSTINE. Yes, you do. I think that it is important to assess whether we are getting what we thought we were going to get. What have our foreign competitors spent? How are they doing? And what can we afford?

To do this before a five-year period is probably not very meaningful. Clearly one wants to monitor progress. But for any significant assessment, even five years is fairly short, because the results of research take so long to appear.

OVERSEAS FACILITIES INVESTMENTS

Mr. MOLLOHAN. We have had three years of Gathering Storm. So we will have something to look at, certainly with those agencies. Of course we struggled actually to double. I would say maybe we are just fulfilling that promise now. But it seems to me personally that this is a particularly appropriate time to look at that and to reset, which is the process we are involved in, because this Administration seems so intent on really fulfilling that commitment as well as rededicating itself or dedicating itself to a new commitment in science and research. And I am sure that has to make the community feel better out there about it.

And I can tell you we are going to be intent on looking hard at that as we make judgements about how we fund these accounts. These observations by you are really—are really very reinforcing.

One more question before I refer to the Ranking Member. International collaboration, we are doing a lot of that. And, again, Dr. Cicerone particularly talked about that. And as a part of that, he made the point that we are investing in science facilities overseas.

Is that good news/bad news? Just first of all, before I follow on with that, what is your thought about that trend? Is it a trend? And what is your thought about it if it is?

Mr. AUGUSTINE. It clearly is the trend. Science in recent years has become very much an international collaborative process. In terms of facilities, it is a trend that is well underway.

Mr. MOLLOHAN. Is that a good thing or a bad thing?

Mr. AUGUSTINE. Yes.

Mr. MOLLOHAN. Yes?

Mr. AUGUSTINE. Speaking as an American who cares about creating jobs primarily in America, not at the expense of others, if others could elevate themselves, that is all the better——

Mr. MOLLOHAN. Yes.

Mr. AUGUSTINE. I am concerned about creating jobs for Americans. And among the things that have led to many breakthroughs in science have been facilities. Those facilities are becoming increasingly costly, some of them measured in multi-billions of dollars.

Given those circumstances, would I prefer that America had its own facilities? In my day it would have been giant wind tunnels. Today it is linear accelerators and other things of that type.

Yes, I would prefer that we have our own facilities in this country just for us. But I also recognize that that is not practicable. To duplicate facilities around the world is like repeating them among companies. Facilities are used for basic knowledge. Duplication of costly facilities isn't appropriate. It wastes too much money.

I think we have to have internationally run and paid-for facilities. That, of course, raises the question, have we given away the advantage that we had hoped to derive? The answer is yes, we have given away part of that advantage. But you can afford to go it alone, an idea which I dismiss because if one isn't a participant, then one is left out of the world's scientific knowledge base. And it is so important that one have access, at least at the same early time as others, to new knowledge. The half life of scientific knowledge is very short.

One of the members of Gathering Storm Commission was Craig Barrett who ran Intel. He told us that on the last day of any fiscal year, Intel's revenues come 90 percent from products that didn't exist on the first day of that same year. So if you can get to the marketplace six weeks faster than your competitors with basic scientific breakthrough, that is a big deal competitively.

Even if you don't start out with a five-yard lead, at least you don't want to start out with a five-yard lag. It becomes a race of how quickly can your engineers take that new knowledge and turn it into products and services that people want. And how quickly can the entrepreneurs and innovators get those products and services into the marketplace.

Mr. MOLLOHAN. When my round comes back I am going to ask you if you would enumerate any of those facilities and technologies that you think are critical to keep here in the United States. But I will give you a chance to think about that.

And I call on Mr. Wolf.

Mr. WOLF. Thank you, Mr. Chairman. I don't know that I have a question. I have been writing notes here. But, you know, I drive a Ford Escort Escape. It is a hybrid. I can't afford a Mercedes. Have you seen the film, " I.O.U.S.A." ?

Mr. AUGUSTINE. I am familiar with it. I have talked to David Walker on the subject.

Mr. WOLF. Yeah.

Mr. AUGUSTINE. But I have not yet seen it.

Mr. WOLF. Yeah. We are broke. And when I listen to some of the witnesses, if it was just a question of us buying another printing press, I think we could fund that right away and get more paper from. And we could just create more money. But we are broke. And in the film it shows us in comparison to China. In essence, we are borrowing money from the Chinese, so we can compete with the Chinese.

And there is something wrong here. And I know a lot of politicians don't want to say anything about it. But there is something wrong. I think it is fundamentally depressing that we are having to rely on the Chinese. Even Hillary Clinton went over to China the other day and didn't want to offend the Chinese, because we need them to buy our paper. I mean, they were hauling people away when she was over there. But she didn't want to raise those issues—cases, because—and in the film " I.O.U.S.A." it shows that.

And you may remember this, although you were young and in college, the British and the French invaded the Suez. And General Eisenhower, President Eisenhower then, told them to get out, and they refused. And Eisenhower said, " Dump their paper." And in two weeks, three weeks they broke down quickly, because economically they were being pretty much controlled by us.

And so I just see it. And in the film it says that in the year 2030, every dollar that comes in will either go to Medicare or Medicaid, Social Security, or interest on the debt, nothing else. Not for math, not for cancer research, not for the inner-cities, not for education.

This year the projection is the deficit is going to be $1.75 trillion and some figure it go to 1.8 to 2. And deficits of a half a trillion for as long as the eye can see. Moody's said we lose their triple-A bond rating. You are a businessman. I mean, what that means for our country. We lose our triple-A bond rating in 2012. Now Iceland just went down the tubes. Lafayette I think did the same thing.

I mean, we would move to paper. Government paper will be junk bond status. So as we talk about the funding, which I am all for, but the Bureau of Prisons need more money, because we have more people in prison than any other country. And something is wrong that we are not having rehabilitation programs. We need more money for cancer research, for autism. I mean, a parent with an autistic child, we should be doing something. I mean, we just have so many needs. But there is no way to pay for it.

And so as I listen to you. I just finished reading the other night this book, " Colossus," by Niall Ferguson. Have you ever read any of his stuff?

Mr. AUGUSTINE. I have heard of him, but I have not read any of his works.

Mr. WOLF. Yeah. He says if this country crumbles, and he is a Brit so he sees it from outside, it will crumble from within. It will not be the foreign power with the military that it will be.

And so I worry about the work ethic. I was telling another witness that this summer down at Nags Head everyone was from Russia, all the young students who work were from Russia. Last year at Avalon everyone was from Bulgaria. Where were the kids from Buffalo? Where were the kids from Fairfax? Where were the kids? I always worked in the summertime and my kids did.

And so I just think some fundamental big issues. And it is like the Simon and Garfunkel song, " The Boxer." A man hears what he wants to hear and disregards the rest. I think as a nation we are just disregarding some of the fundamentals.

So I agree with everything that every witness has said. And I want to thank the Chairman for having these hearings. But I guess if I were 40 I could pretend I don't see the things the way that I do. But I am now 70. And I have these grandkids and these kids.

Dietrich Bonhoeffer, you remember Dietrich Bonhoeffer. He was marched from the Flossenberg Prison and hung as the Western artillery was—he said, " A test of a moral society is what kind of future it leaves for its future generations." And I think we are failing that.

Our inner-city schools are in decay. And the prison system doesn't work. And we are not putting enough into cancer research. We are not putting enough into autism. We are not putting enough into finding a cure for Lyme disease. We are not putting enough into cancer.

And I think we have some fundamental entitlement programs that we just got to deal with. And I am just saying this, you don't have to answer any of it, as you cast votes up here in this institution, the DCCC has a group over there ready to slash and burn you the next day. And my party has one over on my side. And so the first person to cast a vote that looks like they are trying to give more money for this and takes it from something else, your political career, ooh.

And everything is 24-hour news network. And as I said in an earlier hearing, the "New York Times" said it was so important to say that Obama was turning gray, but they didn't cover Pete Peterson's press conference yesterday showing that 56 percent of the people think we have to deal with our economic crisis.

So I hear you, I thank you, and I thank all the others. But I think we all have to come back to the taproom question that is down here that I tell my grandson, Kaleb, working on a Saturday morning. I just bought him a roto-tiller. What am I going to tell Kaleb? How in the good Lord's name are we going to pay so Kaleb can live a life like you lived and I lived?

And I think, frankly, this institution—and I was—I was just as critical. I am waiting to hear this side begin to go after their Administration the way that I criticized the Bush Administration. Paulson brought us to economic ruin. Paulson frankly fiddled while Rome burned. And I say Hillary Clinton had one—Secretary Rice had one of the worst human rights policy we ever had. And so I say it about them.

And I want to hear what—but can we all just—when we get it out, come together to see in a bipartisan way, because the American people are thirsty to see Republicans and Democrats to come together and do what is right for this country, which may very well be very controversial. Henry Hyde in his book that I read about two weeks ago said, " Every member ought to know what they are prepared to be defeated for."

And so we need giants like you that are rapidly leaving the field to begin to speak the truth to people up here and to everybody else. But everything you say is great. But I just come to the bottom line, how are we going to pay for it? And do you have any solutions?

Mr. AUGUSTINE. As you know, I share your concerns. If this were a meeting in Spain in the 16th century when Spain was a global power, I suspect that their citizens would have thought Spain would continue to be a global power. By the 17th century it was France, by the 19th century it was Great Britain, the 20th century the United States. Well, the others are not global powers anymore. A nation can lose that position.

I think we are playing with fire in this country in terms of losing our position. I think that is a very real danger. It comes down to priorities. As I talk to people around the country, they feel a lot like you do. People are scared to death. Ride with a cabdriver.

But I think that it is a matter of priorities. I clipped out from "USA Today" two articles last week. I want to be very careful how I portray the second. One was from the front page. It listed four items, each with very strong adjectives: the stock market was at new low, the federal deficit at new high. Just devastating things. The fourth, however, was a baseball player who had just signed for $40 million for two years. He explained that he had to accommodate the fact that the economy was poor. If that is representative of our priorities, then we will no doubt have great baseball teams. We just won't have jobs for most of our citizens.

The second—not to carry on too long here, Mr. Chairman—in "USA Today," there was a full-page ad about a week ago. It listed several hundred children—high school graduates, high school seniors—who had done terrifically academically. I took just the first 20 to do a sampling. Of that 20, 15 had names that were distinctly Asian. These are U.S. high schools, the best students we have got. Fifteen were distinctly Asian, one was distinctly Indian, and the other three were European-descent sounding names.

Now that is not a very scientific survey, but until the rest of us begin to give some of the attention to education that our Asian community has, I think we have big problems. There is an example, a bright spot right there in this country that the rest of us could learn from.

Mr. WOLF. Well, I agree. In closing, I agree with you. Thanks for your service. We will do that thing we talked about.

And lastly, I do believe the American people are actually ahead of this institution. I think they are ahead. They are ready, and they are prepared to do whatever it takes, because every—do you have children?

Mr. AUGUSTINE. I have three grandchildren and a daughter.

Mr. WOLF. Wouldn't you die for your children?

Mr. AUGUSTINE. Absolutely.

Mr. WOLF. You would die. You would do anything for your children or your grandchildren.

Mr. AUGUSTINE. Die for them in a minute.

Mr. WOLF. And I think America is ready. And I think the failure of this institution is that we are not prepared to do what is necessary for them. But I do believe the American people are far ahead of us. And I think they are just thirsting.

You know, my best friend in Congress, he is a Democratic member, Tony Hall, we still do everything together. We didn't vote together on a lot of issues but some we did. But we do everything together. And I think people want to see this place come together and do some of these things. And if we did some of these things that were tough, and jumped, and linked arms, and jumped off the bridge together, I think it would be the American people would support it.

But thank you very much.

Mr. AUGUSTINE. Thank you.

Mr. MOLLOHAN. Mr. Honda.

Mr. HONDA. Thank you, Mr. Chairman. Do I have ten minutes, about ten minutes?

Mr. MOLLOHAN. Mr. Honda, proceed.

Mr. HONDA. Okay. It has been an interesting discussion. And I think we probably went over a lot of things that were the result of our past actions that we have taken, whether they were sound or not sound. But, you know, we are probably faced with one of the fiscal issues that is a result of past decisions that we have made here in Congress.

But having said that, you know, I have a sense that there was some sense of uplift in terms of expectations. And I heard you mention things like we need more basic research, which we used to cut, and cut, and cut. Now we are in the mode of trying to put that back into effect so that all of our agencies that are geared towards doing research, which we need, to continue the discovery of new information, new knowledge, and then be able to use that, including the need to cover the expense of helping these new ideas to go to commercialization.

I heard that, because we need to help mind the gap. Hopefully, that gets some consideration so that we can make that investment. And realize some of the outcomes of that, because, as you said, two or three percent of the population we are in decides that technology produces about 95 percent of the income.

And I think that when we focus in on the things that we need to do, we might see some sense in that list of youngsters you mentioned. And to me it is not a surprise. And that probably a lot of those youngsters come from families who are recent immigrants, who look at, trying to make sure that they make something of themselves through education. But there is no magic in what they do, because the same thing that recent immigrants from Europe had done, it is called hard work and rigor.

Mr. AUGUSTINE. Exactly.

Mr. HONDA. And so I suspect that, because our smaller population compared to India and to China, the gross numbers we look at should be probably adjusted and looked at in terms of percentages rather than just gross numbers, because of course, you know, the population has got a billion and a half. It is going to have a little bit more—the graduates in different areas. Perhaps their attainment of their—the quality of their instructions may be different. But that is why I think that we are going to stay ahead.

But we can't afford not to—rigorously look at how we can continue to be ahead in terms of education and be innovative. And I think that that is another message you gave us.

So you mentioned that something happens to our youngsters after third grade. Maybe we ought to focus ourselves on what is it that we do to kids. And what is it that the structure does to kids after third grade? Because you are right, children want to come to school. Because there is a study that has been done that some people take the third grade graduation or their attainment academically. Based upon that, they predict how many prisons they are going to need in the future. It is pretty dismal.

So I think that, maybe we could pay some attention to—what is it that we do or we don't do at that place? And I think it is pretty astute that, some of our actions in terms of outcomes that it is quarterly rather than long term. We need to probably shift our similar thinking and not think too much about the shareholders of a corporation but the return on investment we want to make to how much we are going to make and put that into research and everything else that will play out longer. And I think that in that thinking, the shareholders of that arena are citizens and our children and doing the right thing as policymakers.

You know, I think that a lot of the things that you have laid out are pretty important. And I guess the conclusion I come up to is that all these things that we talked about are related. And when we in this Congress talk about trade, I think it determines what immigration—it impacts everything that we do in terms of education or any other policy that we have in this country. So maybe as policymakers we have got to be careful in how we view things.

And so the enemy is not external. Pogo said it, "We met the enemy, and the enemy is us." And so maybe we ought to be internally thinking, because if we depend upon China for, balancing our books, then maybe we ought to think about how not to go into deficit a lot. And right now we have to in terms of the economy. We need to infuse it now. And so there are a lot of reasons why things happen. And putting negatives or positives to it, I think we just look at how do we improve the things that we do.

So I appreciate your presence and your thoughts. Let me wind up my part. The Gathering Storm report that you made, made several recommendations and observations regarding our immigration policy at that time. The immigration policy was aimed at keeping our world's best and brightest students or visiting professors coming to this country to go to school here or to be part of our workforce.

Now given the current economic times and the challenges we think we are faced with, has your—what is your thinking now on the immigration behavior? And what recommendations would you make that would be helpful for our society and for our economic well being?

FOREIGN STUDENTS

Mr. AUGUSTINE. Mr. Honda, at the time we had prepared our report, there was, as you know, a strong reaction to 9/11 which made it very difficult for foreign students to come to this country and even more difficult to stay here after they completed their work, I would submit that America's science, and engineering enterprise, particularly the research aspect of it, would barely function without the foreigners who come to this country. Of the scientists under the age of 40 with Ph.D.s in the U.S. workforce, a little over 40 percent are foreign born. We are highly dependent upon people coming here and staying.

Fortunately, we still have the best universities in the world, and this attracts people to come here. But many of our policies drive them out of the country. And that is an unfortunate policy that we need to correct.

In terms of what needs to be done, our Gathering Storm Members had a number of meetings with the prior Secretary of State with regard to the post-9/11 issues, most of which have been resolved in terms of the short-term issue.

Our recommendation in the longer term is that every person getting a Ph.D. in math, science, or engineering, or another critical skill in this country who is not a U.S. citizen, would be permitted to stay in this country an additional year to seek employment—assuming that they were reputable and could obtain the papers in terms of the risk they might present. At the end of that year if they were able to obtain a job in this country, which most probably would find relatively easy, they would be given priority to become citizens if they wished to do so. They would in any event be given a green card so they could stay in this country and work. If we would do that, we think we could turn around a lot of the loss of talent that we are beginning to see.

Mr. HONDA. The push back on—back on discussion. It generally ends up like well these folks take jobs away from our people. How would you respond to them?

Mr. AUGUSTINE. Yes. I, of course, hear that a lot. My answer would be that these individuals do not just consume jobs, they create jobs for us. The more bright people you can have in a country or in a company, the better off you are going to be. If one looks at the companies in Silicon Valley, a disproportionate number of them were created by people that were not born in this country. There are some wonderful quotations by some of them to the effect that if their families hadn't been permitted to come here 20 years before, their company wouldn't be in this country, it would be in India or in China or perhaps wouldn't exist at all.

Mr. HONDA. Yes.

Mr. AUGUSTINE. I think that for every job that is lost because someone comes here and takes that job, there are ten jobs that are created because somebody brilliant comes here and starts an Amazon or an Intel. There is a long list of those companies that were founded by non-citizens.

Mr. HONDA. I appreciate that. I represent Silicon Valley. And my son graduated from UCLA with a degree in aerospace. I went to his graduation. And this is how I saw it. If you looked at the graduating class, it was maybe three or four hundred students screaming. And they all had black hair, because I was way back in the bleachers. And I asked myself is this one of these examples where we have a lot of folks competing for slots that are limited. A lot of them may be immigrants. And are they taking slots away from other students, which is another argument that we hear? My conclusion is that they may be competing for these slots. This is a graduate program.

But the other question is are we building sufficient universities, and state universities, and colleges to keep up with the demand? And the answer is no, because the time that—going about with the late 1970s to the current time, we built—we broke ground on two new campuses in California, one the University of California and one a state college. And we built something like 10 or 11 prisons.

There is something wrong with that picture. And I think that in this country we have—I still have a lot of faith, and admiration, and hope in this country, because if you look at my own community, my parents wanted us to be doctors and lawyers. They were disappointed when I became a teacher.

But every generation wants their kids to be something. But each generation seems to have an opportunity to have greater choices. And I think that this is what young people are seeing that they have got greater choices other than just being scientists and technologists. We have sports, which is, another avenue for people. But we have other fields, performing arts and things that reflect a higher level of society that the human person can express themselves.

But we don't want to lose our focus on the importance of what science and technology brings to every citizen, that we should teach every child how to think, how to be critical, and how to make decisions. That in itself is important. And we are not doing a good job with that.

So I really appreciate this discussion today, because it has helped solidify some of my thinking. And reinforce some of the things that I think are truth. But we have to be as policymakers clear on everything that we do and responsible to the future. And so, thank you very much.

Mr. AUGUSTINE. Thank you.

Mr. MOLLOHAN. Thank you, Mr. Honda.

Mr. Serrano.

Mr. SERRANO. I will pass.

Mr. MOLLOHAN. Thank you. Well, have you had an opportunity to think about what facilities are crucial or what programs are crucial to keeping within the United States as we consider international collaboration, which I guess is an increasingly happening thing?

Mr. AUGUSTINE. Yes. I am afraid I was listening. Apparently I wasn't thinking about the question.

Mr. MOLLOHAN. Well.

RESEARCH FACILITIES

Mr. AUGUSTINE. I will try to respond. Certain areas in science stand out as being particularly important to be strong in. The information technologies would have to be one. Nanotechnology would certainly be another. Biotech would probably be at the top of the list. The pervasiveness of the breakthroughs in biotechnology are just astounding, from building computers to producing energy, to producing plastics, to feeding humans, to medical advances and so on.

I would probably mention some of the medical fields, cancer research and the likes because of the impact they have on all humanity.

One of the challenges of answering—trying to answer the question you asked is that one is invariably wrong. Typically we have missed the big breakthrough that suddenly shows up and that we never anticipated. I suspect that I will continue our record in that regard.

In terms of facilities, when one visits world-class facilities, for example CERN in Switzerland and France or Biopolis in Singapore, and then visits the better facilities of this country, it is like going back 20 years. We are far behind the best of the best.

We have an overall problem of aging facilities. That makes it difficult to attract people to science, to encourage foreign students to come here. By this I mean enough room in a laboratory, instrumentation, the mundane things that it takes to perform science. But I also mean the big science. The biggest of all is probably the linear accelerator. That inevitably will be an international program because of its cost. And I don't have any problem with that.

Regarding some of the advanced computing capabilities, I think it is important to maintain a lead not only for the impact on science but the impact on national security and intelligence.

Those are the areas that to me stand out. I suspect people who live in the world of facilities probably could answer better than I.

Mr. MOLLOHAN. Well, Mr. Augustine, thank you very much for your testimony today. And in the same breath, let me, again, thank you for your service. As the Ranking Member noted, you are an exceptional corporate citizen who has been relied upon disproportionately to many others. And I know that has been in and of itself a service by you to the country.

I look forward to working with you in the future. If there are any thoughts that you have that you would like to put on paper, you know, after this hearing, we would certainly appreciate the benefit of them.

Thank you so very much for your testimony here today.

Mr. AUGUSTINE. Thank you, Mr. Chairman, and your Committee for the leadership you are providing in this area. It is greatly appreciated.

Mr. MOLLOHAN. Thank you.

TUESDAY, MARCH 17, 2009.

STATUS OF CLIMATE CHANGE SCIENCE

WITNESS

DR. SUSAN SOLOMON, PH.D. NOAA EARTH SYSTEM RESEARCH LABORATORY

OPENING STATEMENT BY CHAIRMAN MOLLOHAN

Mr. MOLLOHAN. The hearing will come to order.

Welcome. Good morning, Dr. Solomon, and welcome before the Commerce, Justice, Science, and Related Agencies Subcommittee. We appreciate your coming today to provide your perspective on the status of the scientific understanding of climate change and predictions.

As those responsible for appropriations for the federal agencies with the largest budgets for climate change science, NSF, NASA, NOAA, we want to ensure that we provide appropriate support for improved understanding, monitoring, and prediction of climate change.

We also have responsibility for virtually all civil earth observing satellites, both research and operational.

We have had to confront major cost overruns in the NOPE SS Program and additional requirements appear likely given the anticipated need to support operational climate predictions and monitoring.

In our hearings this week, we will explore the role of satellite data in observing climate change. Our second and third hearings will focus on examples of ongoing satellite observations of land vegetation, ice sheets, ocean and atmospheric properties, and what is required to sustain these critical environmental records.

Our final hearing will look forward to the future of satellite climate observations and the relationship between NASA and NOAA, between research and operations, and how that may be a help in controlling future costs.

Today we look forward to establishing a foundation for our satellite considerations by gaining more understanding of climate change and the requirements its study and observation place upon the programs in our jurisdiction.

Dr. Solomon, your written statement will be placed in the record. And before I ask for your oral testimony, I recognize our distinguished Minority leader, Mr. Wolf, for any comments he may have.

Mr. WOLF. I do not have any. Thanks.

Mr. MOLLOHAN. Dr. Solomon, as I said, your written statement will be made a part of the record and you proceed as you will. Thank you.

Opening Statement by Dr. Solomon

Dr. Solomon. Thank you very much. Thank you for the opportunity to talk to you today.

I would like to summarize the state of knowledge of climate change science. I will base that mainly on IPCC's 2007 reports as well as other assessments by the U.S. National Academy of Sciences and the U.S. Climate Change Science Program.

I would like to describe my view of key advances in understanding that have occurred since the reports were issued as well.

Warming is unequivocal. That is evident in independent sets of measurements that all attest to the long-term changes in the climate. Among those are increases in global average surface air and ocean temperature, widespread loss of snow and ice, and rising global average sea level.

We actually chose to express that finding in unusually strong language during the IPCC report process and that is because we have so many different sets of data that all document changes in a variety of observables.

Last year, 2008, is estimated to be the tenth warmest year on record since observations began to be systematic about 150 years ago and that shows that global warming is still apparent since the IPCC report was finished.

It is clear that the primary driver of climate change is increased carbon dioxide, which is produced by fossil fuel burning, and to a lesser degree by deforestation. Today's levels of carbon dioxide are about 385 parts per million parts of air and that is unprecedented in more than half a million years of data from ice cores.

In the past few years, since we completed the IPCC report, the rate of increase of carbon dioxide has been faster than ever observed in the instrumental record and that is due to increased global fossil fuel use.

By the end of the 21st century, carbon dioxide concentrations could become as high as 1,000 parts per million if emissions worldwide keep increasing at the type of rates we saw in the last decade, which were about two percent per year. And with a sustained level of 1,000 parts per million of carbon dioxide, an average day would be about ten degrees Fahrenheit warmer than today.

Heat waves as bad or worse than the worst current heat waves would become common. Decreased rainfall would be expected in parts of southwestern North America, west Australia, southern Europe, and both northern and southern Africa. We have much higher confidence in that now than we did a few years ago.

Droughts comparable to a dust bowl would be expected to occur in all of those places. Fires would become more common in those places and fire frequency would also be expected to increase in many places that are dependent on snow pack for their water supply, such as much of California.

Glaciers and snow pack that provide water to at least a billion people in Asia would disappear. Insect pests would become more common, which would damage crops as well as forests. In short, it would become a very different world.

All of those impacts are based on physical processes that are well understood and represent pieces of the science for which the confidence is very high indeed.

I would now like to very briefly talk about some key uncertainties. As the world warms, land and ocean uptake of carbon dioxide decreases and there is some evidence that large amounts of carbon could be released from melting permafrost in the Arctic.

Those feedback processes are very uncertain, but they have the potential to substantially enhance future carbon levels. We need a much better understanding of the cycling of carbon.

But carbon dioxide is not the only thing that is causing our climate to change. It is the largest factor, but it is not the only one. Mitigation efforts directed at other climate change agents such as reduction in soot, ozone, or methane could have very useful co-benefits for air quality and related health effects. And it is really the suite of driving agents and options that needs to be considered.

Climate change is not limited to warmer temperatures. It extends to water, storms, sea level rise, snow pack, heat waves, flooding, fire, and really much more. So improvements to numerical modeling, process studies and analysis and monitoring will all be needed to provide the kind of information required for many decisions, especially local adaptation decisions.

Improved numerical simulation at smaller scales is a pressing issue in research. Networks to monitor how climate is changing are generally considered to be barely adequate. Some are in danger of being lost altogether.

Measurements of rain, snow, clouds, humidity, tropical and mid latitude storms, solar radiation, aerosols, and many greenhouse gases are all examples of key areas for monitoring and process studies.

Increasing carbon dioxide increases the acidity of the oceans through very well-estimated chemistry and the increases in acidity have the potential for vast effects on marine life and ocean ecosystems. We do not understand that very well at all at the moment.

The sea level rose by about six inches in the 20th century. How much will it rise in the future? Well, expansion of warming water and melting of small glaciers are well understood and they can be expected to produce up to three feet of sea level rise within about two to three centuries. That is enough to inundate many small islands and regions such as Florida.

But there is a wild card in the sea level problem, a third process that is very poorly understood. That is rapid flow of ice from Antarctica and Greenland. There is evidence for locally rapid ice flow, but it is not yet possible to integrate that contribution over the full size of the ice shape to quantify the total contribution to sea level rise. It could be on the order of a few meters over centuries, but it is very uncertain.

Those are a few of the questions facing the nation and the world as the climate continues to change. There is much that we do know. There is also much that we do not know.

Thank you very much for the opportunity to speak with you today.

[The information follows:]

WRITTEN TESTIMONY OF
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NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

BEFORE THE
SUBCOMMITTEE ON COMMERCE, JUSTICE, SCIENCE,
AND RELATED AGENCIES
COMMITTEE ON APPROPRIATIONS
U.S. HOUSE OF REPRESENTATIVES

MARCH 17, 2009

I thank Chairperson Mollohan, Ranking Member Wolf, and the other Members of the Subcommittee for the opportunity to speak with you today on the state of climate change science. My name is Susan Solomon and I am a Senior Scientist at NOAA's Earth System Research Laboratory in Boulder, Colorado. I've been a scientist at NOAA for more than 28 years. My work has focused on understanding both ozone depletion and climate change. In 2000, I received this nation's highest scientific award, the National Medal of Science. I've also been honored with membership in the U. S. National Academy of Sciences and I am a foreign associate of the French Academy of Sciences, the Royal Society of London, and the Acadamiae Europaea. I'm the author or co-author of more than 150 scientific publications. I've served as an author on various reports of the Intergovernmental Panel on Climate Change (IPCC) beginning in 1992 and as co-chair of IPCC's fourth major climate science assessment report released in 2007.

I would like to summarize some aspects of the process and primary findings of IPCC's 2007 reports, and to describe my view of key advances in understanding that have occurred since the reports were issued. I'll identify key findings that can be considered well understood on the basis of both observations of climate change and physical understanding of the processes involved. I'll also identify aspects of climate change science that are not as well observed or understood, and are therefore subject to larger uncertainties.

Since its inception about 20 years ago, IPCC has produced assessments of the state of understanding of (i) the science of climate change, (ii) the impacts of climate change and climate change vulnerability, and (iii) mitigation of climate change. Each of these areas is the subject of a separate scientific assessment, and there is also a synthesis summarizing findings across all three. The IPCC does not carry out or manage research. The mandate of the IPCC is to evaluate information that must be independently documented, primarily as peer-reviewed literature. IPCC's reports have become the gold standard for authoritative scientific information on climate change because of the rigorous way in which they are prepared, reviewed, and approved. The 2007 IPCC climate science assessment was prepared by 152 leading scientists from around the world who served as its authors. It was then reviewed and re-reviewed by more than 600 experts and dozens of governments. All of the review comments and responses have been made publicly available. The comprehensiveness of the literature considered, the scope of the evaluation, as well as the robustness of the findings were all subject to extensive review. Completion of an IPCC assessment report requires a demanding line-by-line approval of its summary that is critical for its value to policy-makers, and must also be acceptable to the authors involved. This process ensures that key conclusions are scientifically accurate. It also ensures that findings are accepted by all governments and expressed in language that is useful to policy.

Among the key conclusions and updates to IPCC's 2007 report are the following:

Warming is unequivocal, as is evident in independent sets of observations all attesting to long-term changes to our planet's climate. Among these are increases in global average surface air and ocean temperatures, widespread losses of snow and ice cover, and rising global average sea level. The finding that warming is unequivocal is one that the authors chose to express in unusually strong terms, which stems from the diverse sets of independent data documenting changes in many different observables. Climate may be defined as the weather averaged over a period of about 20-30 years. Globally averaged, today's temperatures are about 0.75°C or about 1.3°F warmer than they were 100 years ago. In a world that is warmer on average there is still variability from year to year or season to season. Since the 2007 IPCC report, it's been noted that a La Nina event contributed to making global temperatures in 2008 slightly cooler than some other recent years, but it was nonetheless much warmer than La Nina years that occurred in the early part of the 20th century. Indeed, despite the presence of a La Nina, 2008 is estimated to be the tenth warmest year since systematic global thermometer records began about 150 years ago, showing that global warming remains apparent.

IPCC's 2007 report noted the observation of increases in water vapor in association with the observed global warming. This occurs because warmer air can hold more water vapor. Multiple scientific studies have continued to support and extend those observations since the 2007 report appeared. While water vapor is a very important greenhouse gas, it responds to and amplifies climate change rather than being an independent driver of climate change. It is a feedback to climate changes forced by other factors but is not a significant forcing agent.

It is clear that the primary driver of climate change is increased carbon dioxide produced by fossil fuel burning, and to a lesser degree by deforestation. Today's levels of carbon dioxide are about 385 parts per million parts of air, and this is unprecedented in more than half a million years of data from ice cores. Carbon dioxide has increased by about 30% compared to observations prior to the industrial era, and in the past few years the rate of increase of carbon dioxide has been faster than ever observed in the instrumental record. This is due to increased global fossil fuel use. These changes in carbon dioxide have increased the acidity of the global surface ocean through well-understood sea water chemistry. It is well understood that a substantial portion of the carbon dioxide remains in our atmosphere for a very long time even after emissions stop: about 20% of today's emitted carbon will remain present in the atmosphere for more than a thousand years and will therefore alter the Earth's climate for many human generations. Other greenhouse gas forcing agents including methane, nitrous oxide, and halocarbons have also made significant but lesser contributions to global warming.

IPCC's 2007 report examined the distribution of temperature changes in time, latitude, longitude, and altitude, and compared these to physical understanding of the processes involved and to numerical model simulations that incorporate those processes. Land areas are warming more than oceanic regions, as expected from physical understanding and models. Higher latitudes in the Arctic are warming more than mid-latitudes. This is expected, because the process of snow and ice retreat decreases the reflectance of energy to space and allows more energy to be absorbed by the Earth's surface. This amplifies the high latitude warming. The Earth's surface and the atmosphere are warming globally up to about 10-15 km altitude, while temperatures are cooling at higher altitudes in the stratosphere, just as expected based on our understanding of greenhouse gases and ozone depletion. In contrast, larger warming would be expected in the upper atmosphere if increased levels of solar activity were responsible for the observed surface warming, so that is opposite to what is observed and suggests a small role for solar changes. Based on these and other patterns that represent fingerprints of the observed climate change, IPCC's 2007 report concluded that most of the global warming of the past half century was attributable to manmade increases in greenhouse gases at a 90% level of scientific certainty. Recent published work continues to support that conclusion. For example, IPCC carefully considered the possible contributions of changes in the sun's brightness to the observed warming. Direct high-quality observations of the brightness of the sun since 1979 show very small long-term changes in the sun over the period of the last three decades, when most of the global warming occurred. Since the 2007 IPCC report appeared, there have also been studies showing that cosmic rays have not increased significantly, providing direct evidence that solar cosmic ray/climate mechanisms don't account for a significant part of the current warming.

Among the key findings of IPCC's 2007 report was information not just about temperatures, but also about other changes in the climate system. IPCC's 2007 report presented observations and model simulations of changes in rainfall, and recent studies including the 2008 Climate Change Science Program (CCSP) assessment of weather and climate extremes have supported those conclusions. Among key robust conclusions is the finding that warming is associated with changes in rainfall patterns. In particular, the already-dry regions just outside the tropics are becoming drier, while wet regions at high latitudes are becoming wetter, and this is expected to worsen as the world continues to warm. There is also strong observational evidence that the frequency of heavy rainfall has increased and will continue to increase in the future, implying greater frequency of flooding.

I'd now like to briefly turn briefly to some robust aspects of climate change projections and impacts. By about the end of the 21st century, carbon dioxide concentrations could become as high as 1000 parts per million if emissions worldwide continue rising at a rate typical of the last decade, which is about 2% per year. The best current science implies that with a sustained level of 1000 ppmv of carbon dioxide, an average day would become about 10°F warmer than today, which corresponds to a greatly changed climate. Heat waves as bad or worse than the worst current heat waves (such as the one in Europe in 2003 that led to the deaths of more than 10000 people) would become common. There is now increased confidence that decreased rainfall can be expected as the world warms in parts of southwestern North America, west Australia, southern Europe, and both northern and southern Africa. Droughts comparable to the dust bowl can be expected to occur in the future not just occasionally in limited regions, but in all of these places and at the same time. Many of the world's most desolate deserts would expand as semi-arid soils dry out. Glaciers and snowpack that provide water to at least a billion people would disappear. Fires would become more common in these dry regions, and fire frequency is also expected to increase in many locations that are dependent upon snowpack for their water supply, such as much of California. Insect pests would become more common, with attendant damage to crops and forests. All of these impacts are based on physical processes that are well understood, and represent aspects of the science for which confidence is very high.

The amount of carbon dioxide in the atmosphere is sometimes usefully compared to the water level in a bathtub for the purpose of illustration. We are currently pouring carbon into the system, providing a tap at a rate much bigger than the drain can take it away (that drain is mainly absorption into the ocean and biosphere). The water level in the bathtub will keep rising unless the amount of water coming in equal to or less than what is removed, so the emission required to balance the carbon removal is important. If the world chooses to stop carbon dioxide increases and the attendant global warming at any level: 2°F, 4°F, or something else, this would require a reduction in global carbon emissions by at least 80%. *When* we cut emissions would affect how much total warming occurs, so decisions and actions on timing are important in determining the extent of the human-induced climate change that we can expect. But the drain has to ultimately match the tap if carbon dioxide is to be stabilized at any point, and this illustrates why mitigating climate change is a very substantial challenge.

I will now turn to key uncertainties. Society is clearly facing a vast array of decisions about climate change. Decision-makers ranging from national, state, and local levels as well as businesses, and citizens are increasingly seeking more climate change information as input to their choices. Policy makers and citizens worldwide are seeking more information regarding the design of future actions under the United Nations Framework Convention on Climate Change and the Kyoto Protocol: how dangerous is climate change is a frequent question, what are options for actions, how fast is the climate expected to change, etc. I will provide some illustrative but far from comprehensive examples of the many ways in which more research is needed to better inform current and future choices about mitigation, adaptation, and some key fundamentals of climate change.

Some scientists have suggested geoengineering to remove the carbon dioxide or to actively cool the climate as an alternative approach to emissions reductions. I do not have the expertise to comment on the engineering aspects of these. However, many of these proposals have the potential for uncertain climate side effects that would require more research to ensure a firm foundation. For example, schemes to reflect sunlight could cool the climate, but they could also reduce evaporation of surface water and affect the water cycle and rainfall. More research is needed before such approaches can be considered safe to present as options.

As the world warms, land and ocean uptake of atmospheric carbon dioxide decreases, increasing the fraction of anthropogenic emissions that remain in the atmosphere and enhancing the warming per pound of gas emitted. There is also some evidence that large amounts of carbon could be released from melting permafrost in the Arctic as the world warms. These feedback processes are very uncertain but have the potential to substantially enhance future carbon levels. Their effects could become large enough to make it much more difficult to stabilize carbon dioxide concentrations should we choose to do so. There is hence a need for much better understanding of the cycling of carbon and the ways in which climate change affects it.

As already noted, carbon dioxide is not the only agent causing our climate to change, although it is the largest one. Other anthropogenic greenhouse gases and some aerosols provide additional opportunities for climate change mitigation. Some of these, such as reductions in soot, could have important co-benefits for air quality and related health effects. Other options include improved containment or substitution for hydrofluorocarbons in, for example, automobile air conditioners, and some of those emissions reductions may be relatively easy to achieve. There is a potential for trading in a basket of such choices among climate change agents, but there is limited information on factors such as the effectiveness of such trades over time, and more research is needed to ensure that the broadest range of practical climate change mitigation options are considered.

As alternative sources of energy are sought such as biofuels, wind or solar energy, new questions arise regarding those options, such as how local climate changes may influence the availability of the water required to produce biofuel, or how a large solar or wind array might modify local climates. There is very limited information now available to guide key choices between such mitigation alternatives, and increasing demands for such information.

Critical questions are being raised regarding how best to adapt to climate change, through such measures as coastal infrastructure choices, changes in water management, farming practices, and much more. But information about local climate changes at the required spatial and temporal scales is currently subject to very large uncertainties in many cases. Improved numerical simulations at smaller scales is a pressing issue in research.

Climate change is not limited to warmer temperatures but extends to water, storms, sea level rise, heat waves, flooding, fire, ecosystem feedbacks, and much more. While there is an emerging understanding of all of these scientific topics, improvements in numerical modeling, process studies and analysis, and monitoring will all be needed to provide the kind of information required for many decisions. I have already referred to the probable loss of water supplies in certain parts of the US such as the southwest and California, and while this is understood in broad terms much more information is needed to assist local water management choices. In other regions of the US, our ability to project rainfall changes with warming is generally much less clear but no less important. Similarly, there are many questions regarding how hurricanes could be affected by climate change. Although there is some evidence for increases in the intensity but not the number of the most intense storms, much more research is needed. Whether and how the intensity and frequency of El Ninos and La Ninas could be affected by climate change remains a research question, one that has large implications for many aspects of our climate. Networks to monitor how these and other aspects of climate are changing are generally considered to be barely adequate and some are in danger of being lost altogether. Sustained observations are essential to ensure that key records are not lost; better and broader observations and systematic analysis would help us to ensure that we are aware of climate changes as they evolve and can better understand and characterize them. Measurements of rain, snow, clouds, humidity, tropical and mid-latitude storms, solar radiation, aerosols, and many greenhouse gases are all examples of the key areas for monitoring.

Observations demonstrate that Arctic sea ice extent reached record low levels in the late summers of both 2007 and 2008. It is very likely that the Arctic sea ice retreat is driven at least in part by global warming, but the extreme reductions of 2007 and 2008 are not fully understood. There is some evidence that unusual wind patterns played a role along with warming. Similarly, the changes in Antarctic sea ice appear to be driven in large part by changes in wind patterns. So while changes in polar sea ice are well documented, and there is important evidence for human contributions to those changes, other factors are also likely to play some role and future projections are hence uncertain.

While ocean acidification is evident and is controlled by well-established chemistry, it is less clear how the acidity increases will impact life in the ocean. Increasing acidity of the world's oceans has the potential for vast effects on marine life and ocean ecosystems, but the degree to which various organisms may be capable of adapting to a more acidic environment is uncertain, and more research is badly needed.

Sea level rose by about 6 inches in the 20th century. How much further it will rise in the future is not well understood. It is well established that water expands when heated, and this is an important source of sea level rise. It is also clear that small glaciers worldwide have lost mass as the world has warmed, supplying more liquid water to the ocean and contributing to sea level rise. These two processes are well understand and can be expected to produce up to 3 feet of sea level rise within about the next two to three centuries if carbon dioxide continues to increase. Three feet of sea level rise would inundate many small islands and low lying coastal regions, such as Florida, and this is already becoming part of coastal planning in many regions. A third process may be very important but is very poorly understood, rapid flow on the great ice sheets of Antarctica and Greenland. There is evidence for locally rapid ice flows, but it is not yet possible to integrate this contribution over larger areas as would be needed to quantify the total contribution to sea level rise. The potential contribution could be on the order of a few meters over centuries, but is very uncertain.

These are but a few of the questions facing the nation and the world as the climate continues to change. There is much that we do know. There is also much that we don't yet know that is especially important to particular mitigation and adaptation decisions.

Thank you again for the opportunity to provide this testimony.

ATMOSPHERIC CARBON DIOXIDE

Mr. MOLLOHAN. Thank you, Doctor. We do appreciate your coming to speak to us.

You said somewhere in the early part of your testimony, I think, if I understood it, that today's levels of CO_2 in the atmosphere are the highest that they have ever been since the presence of mankind, did I understand you to testify, already right now?

Dr. SOLOMON. The highest they have been in half a million years. And depending on how you define mankind, that certainly exceeds, I think, any definition of mankind. You know, Cro-Magnon man has been on the planet for I think about 30,000 years. So half a million years is way past the Cro-Magnon man. It is way past neanderthals. It is a long way back.

Mr. MOLLOHAN. And you know that from ice core samples?

Dr. SOLOMON. Yes. The little bubbles that are trapped in the ice are analyzed to provide the amount of carbon dioxide. And that has been done both in Antarctica and Greenland. And one of the things that is really nice is having both of them. You can go back quite a ways, over 100,000 years with both of them, and see the same kinds of things.

SEA LEVEL RISE

Mr. MOLLOHAN. Uh-huh. Well, sea level rise looms large as perhaps the most significant consequence of global warming and this rise is predicted by the Intergovernmental Panel on Climate Change to be between .6 and two feet in the next century.

And as you testified, does that predicted range include the effects of major decreases in ice sheets or is it simply due to the thermal expansion of world oceans? And you in your testimony, part of your uncertainty was the impact of ice sheet. If you would elaborate on that for us, please.

Dr. SOLOMON. The IPCC was able to quantify certain terms that contribute to sea level. One of them, as you said, is the thermal expansion of the ocean. That is well understood. When you make a cup of tea, you see the water expand and that happens in the ocean as well.

But that is not the only term we were actually able to quantify. We also include the effect of the loss of small glaciers worldwide, so glaciers in the Andes and Europe and Alaska and places like that. That term was also included.

We have a number of other small terms that I will not go into, but you are absolutely right. The key term that we simply do not have enough information to quantify is the melting of the great ice sheets of Greenland and west Antarctica.

And the physics is poorly understood, but what we know is that we see rapid ice flow on those ice sheets. So it is fast. It is impressive. I am sure you have all seen photographs of it. But it is not understood well enough to be numerically simulated in terms of how it will behave in the future. We just do not know how it is going to behave in the future.

Mr. MOLLOHAN. Are there any predictions out there for the west Antarctic ice sheet or the Greenland ice sheet?

Dr. SOLOMON. There is more information for Greenland and there is an estimate that suggests that if all the variables are pushed to their limits, we could see a change of about two meters by 2100. So that is, I think, a fair estimate of the upper limit from Greenland.

Mr. MOLLOHAN. Just from the Greenland ice sheet melt?

Ms. SOLOMON. Yeah. I believe that may also include thermal expansion. I believe that may be that person's best estimate of the total upper limit range. I would have to check that, but I am pretty sure that is true.

For west Antarctica, I think the numbers are much less certain. That kind of analysis has not been done there. The real problem is we see these things happening locally. We know they are very important locally, but we do not know how important they are integrated across the ice sheet and we do not know how they are going to behave in the future.

There is some evidence that you may see transients where you get a fast, rapid flow for a little while and then it stops. So it is really quite difficult to project. We just do not understand the physics well enough.

DEFINITION OF GLOBAL WARMING

Mr. MOLLOHAN. Okay. Now, there are a huge number of people in the world who, or it seems like there are a huge number of people in the world who suggest that this is natural phenomena and whether man is contributing to it or not. I am not sure whether they dispute that, but they do suggest that the world has gone through these cycles without the contribution of human activities. And, therefore, I suppose, I do not want to speak for them exactly, but perhaps they just say it is inevitable and not that it is good or bad, but that it is inevitable.

First I would like for you to define for us what is global warming and then relate the impact of that to climate change and its consequences. What is global warming, the phenomena of global warming, the chemical or the whatever?

Dr. SOLOMON. Well, I——

Mr. MOLLOHAN. If you can do that for us in a way we can understand, that would be extremely——

Dr. SOLOMON. I will try. I will try.

Mr. MOLLOHAN [continuing]. Helpful.

Dr. SOLOMON. I would say that global warming is the change in our planet's climate that is being induced by the things that people do. So it is mostly carbon dioxide increases, also other terms like soot, methane. There are a number of different things that are contributing to that.

I think perhaps what is really underlying your question is how do we know this is unusual.

Mr. MOLLOHAN. No. Really the first thing that is underlying my question is what is the phenomena. You have got sun coming in. It is in some way being affected by CO_2 concentrations. That is somehow, as some of the experts have tried to explain to me, reacting in ways that is creating heat, that is infrared, and it is bouncing back up, that it cannot get out. And, therefore, the heat cannot get out and, therefore, really assume that we could understand it if you were to elaborate on it.

Dr. SOLOMON. Okay. You are absolutely right. The sun is the primary source of heat to the earth. We all know that from going to the beach. The sun is what heats the earth. The earth tries to cool off by radiating in infrared.

And if you have ever seen, for example, night photographs, infrared photographs that people sometimes use, for example, in hunting and such things, you can appreciate that all objects have a temperature and then they radiate their energy in infrared.

Basically what carbon dioxide and other greenhouse gases do is to keep some of that energy in, so it keeps it from escaping out to space. All the other planets do that. I should say all the planets that have atmospheres do that just as our sun does.

And one of the things that I think is really a very beautiful illustration of global warming is, or at least of the greenhouse effect, I should say, is the fact that Venus has a greenhouse effect, too, because it also has an atmosphere. And that keeps Venus much hotter than it would otherwise be.

In fact, one of the reasons Venus is hotter than earth is not so much that it is closer to the sun. It is actually because its atmosphere has a tremendous amount of carbon dioxide and also some sulphur compounds that all contribute to——

Mr. MOLLOHAN. So——

Dr. SOLOMON [continuing]. Its greenhouse effect.

Mr. MOLLOHAN. So there is——

Dr. SOLOMON. When you put in—sorry.

Mr. MOLLOHAN. No, no. I am sorry. You go ahead.

Dr. SOLOMON. When we put in carbon dioxide into our atmosphere by our activities making that gas, which is a major greenhouse gas on our planet, 30 percent higher than it has been in half a million years, that is causing the planet to warm up along with some other factors, but it is the main one. And the net result is a temperature that is about a degree, 1.3 degrees Fahrenheit——

Mr. MOLLOHAN. So it is fair or accurate or useful to see CO_2 as a catalyst and a compound in the atmosphere that inhibits the radiation of heat back out of the earth and so the increased levels of CO_2 exasperate this process so that less heat, more CO_2, keeping more heat into the atmosphere in the earth and, therefore, creating an increase in temperature? And that is a phenomena we have not seen during the age of mankind?

Dr. SOLOMON. That is correct. It traps the energy. Absolutely.

Mr. MOLLOHAN. Mr. Wolf.

Mr. WOLF. Thank you, Mr. Chairman.

Doctor, welcome.

What of the causes, if you had to break it down percentage manmade and not manmade or manmade and natural, how would you break that down?

CAUSES OF GLOBAL WARMING

Dr. SOLOMON. That is a good question. The manmade causes of the enhanced temperatures that we have now is mostly carbon dioxide to the tune of, I believe, about 60 percent of today's global warming. Methane also contributes. The chlorofluorocarbons and their replacements, hydro fluorocarbons and hydro chlorofluorocarbons also contribute. Nitrous oxide also contributes. So there is sort of a range of other gases that contribute as well, but it is roughly 60 percent carbon dioxide, a small amount from soot also, which is again manmade.

The natural forcing agents are two. There is the sun which if it gets brighter can cause some warming. But we have good measurements of how bright the sun has been since at least 1979 and it has contributed very little over the period, at least since 1979.

So I think a fair number on that, I do not have it in my head. I am sorry. But it is certainly less than ten percent, I think, is a fair statement.

Volcanos actually cause cooling and we have had a number of volcanos over the last 30 years or so. They only cool for a little while, for a few years. So they have actually worked, though, to cause a slight cooling effect.

So the volcanos and the sun are the natural terms. They are quite small. The overwhelming cause of what we are seeing today is certainly manmade chemicals, particularly carbon dioxide, but also some of these other chemical agents.

SOLUTIONS FOR GLOBAL WARMING

Mr. WOLF. And what do you see as the solution? We hear stories of cap and trade. I have an article here from the Washington Post that was on June 26th of a year ago. It said with regard to global warming, it said the answer—this is by a gentleman, maybe you know him, an adjunct professor at the Copenhagen Consensus Center, Bjorn Lomborg. Does that name ring a bell, L-O-M-B-O-R-G?

Dr. SOLOMON. Yes.

Mr. WOLF. What do you think of him? I do not know anything about him.

Dr. SOLOMON. I have never met the man.

Mr. WOLF. But that is not an answer. I never met Lincoln and I think he was one of the greatest Presidents that we ever had.

Dr. SOLOMON. Indeed. Indeed.

Mr. WOLF. And Washington and Jefferson. So what do you think of him?

Dr. SOLOMON. I have read his books. He has some useful points to make and some of his points, I think, are not as useful. I am not prepared to give you a complete review of his work at the moment. He certainly has received a lot of attention for his studies. He has also, I think, been censured by the Danish Academy of Sciences.

Mr. WOLF. For?

Dr. SOLOMON. That is probably all I can tell you.

Mr. WOLF. For what?

Dr. SOLOMON. Scientific misconduct, I believe, was the words they used.

Mr. WOLF. Can you supply that for the record, so I can see what it is, or just send me a copy?

Dr. SOLOMON. I will certainly look up what the Danish Academy of Sciences——

Mr. WOLF. What he says in here is the answer is to dramatically increase research and development so that solar panels become cheaper than fossil fuels sooner rather than later. Imagine if solar panels become cheaper than fossil fuels by 2050, we would have solved the problem of global warming.

But what is your thought about the idea of putting more money into research and less into cap and trade as a solution?

He also goes on to say the economists have, they have pointed out that a better response than cutting emissions would be to dramatically increase research and development on low carbon energy such as solar panels and second generation biofuels.

SEPARATION OF SCIENCE AND POLICY

Dr. SOLOMON. There are a lot of different opinions on what we ought to do about this issue. I am not an economist and I cannot judge what would give us the fastest result for an improved climate. There are those people who argue that strong investment in technology would pay off so well that nothing else should be required. I am not an expert enough to——

Mr. WOLF. Well, what do you feel between cap and trade and this concept of greater investment? What do you think has the best opportunity for——

Dr. SOLOMON. Boy, if I knew what to do, I would be happy to tell you, but honestly I think it is just so difficult to project the future of economic problems that I am at a loss to know what——

Mr. WOLF. I think, though, frankly, there may be some exceptions, but my sense is most Congressmen do not know what to do either. And if you do not know what to do, I think I would say there probably are not any Congressmen that really know what to do.

And I think the scientific effort, and I think it has to be scientifically driven, is very, very important. So I think that it is important to put together a group of people like yourself, but men and women who we have the respect in for to sort of come up with some solutions.

The real danger is you could move ahead and into a particular area and then find out that that is not the way to go and have spent a tremendous amount of money and have a major impact on the economy.

Would you agree with that?

Dr. SOLOMON. Yeah. I think those comments are all fair. I think that the issue that to me is particularly important is that we not attack the science basis because we do not like the policies.

Mr. WOLF. I agree. No. That is what I said.

Dr. SOLOMON. Policies are——

INTERNATIONAL GROUP TO LOOK AT CLIMATE CHANGE

Mr. WOLF. To put together a group of men and women who are experts in the field, well respected to come up with a proposal or an idea, rather than this being a political issue to be a scientific issue.

Dr. SOLOMON. Yeah. I do not disagree with that either. But I think it is important to recognize that there is the question of how much climate change we think we are prepared to accept and at what point do we begin to take actions because we have to weigh the concerns for our economy against the concern for issues like droughts and heat waves and the number of people whose lives will and livelihoods will be damaged.

The Framework Convention and the Kyoto Protocol all certainly recognize the importance of weighing the damage to the environment along with the damage to the economy.

INTERNATIONAL COOPERATION

Mr. WOLF. How significant is it that China participate in whatever is done?

Dr. SOLOMON. China's emissions today are about the same as ours, so——

Mr. WOLF. Well, according to an article here, I would like to get your comment on it, it was in today's Washington Post, and when I was reading, eating my breakfast, I saw, thinking of this hearing, that said, this is in page A4 of today's Washington Post, countries importing Chinese goods should be responsible for the heat trapping gases released during manufacturing.

A top Chinese official said yesterday, Li Gao, G–A–O, China's top climate negotiator—do you know him?

Dr. SOLOMON. No.

Mr. WOLF. Said any fair—this is the country that has 30 Catholic priests in jail and have a lot of Protestant Pastors and has plundered Tibet and is spying on us, but he said any fair international agreement to curb the gases blamed for global warming would not require China to reduce emissions caused by goods manufactured to meet demands elsewhere.

Then it goes on to say, according to the Associated Press, which I think would differ, but China has surpassed the United States as the world's largest emitter of greenhouse gases. About 15 to 25 percent of its emissions are generated by manufacturing goods for export.

So this article, I do not know what they base this on, says that China has surpassed us. But what are your thoughts about Mr. Gao's comments that China should not be blamed for global warming and that they should not be required to have to deal with it, only the country that the exports are going to?

Dr. SOLOMON. Well, they probably have surpassed us slightly in the last couple of years, but I think it remains to be seen how the current economic downturn will affect their emissions for last year, say, compared to ours.

So, yes, they have surpassed us, but, you know, they have not surpassed us by a country mile. They may have surpassed us a little bit. And I think the adjustments that are happening have yet to be realized for any nation as far as emissions go.

Mr. WOLF. We are closing factories faster than opening them. They are opening them and we are closing them. So I think that is the direction.

So, again, a comment, how important is China in the participation of solving or dealing with the problem of global warming? Could you successfully deal with the issue, whatever the solution may be, without having China as a participant?

Dr. SOLOMON. It is clear that the developing country contribution in the future is very likely to be large. There are five and a half billion people living in the developing world, only a billion in the developed world. We produce about ten times more carbon dioxide per capita per year than the rest of the world. We still produce about four times as much per capita as China even. Even though their total amount is larger than ours, because they have so many more people, we are producing four times more than they are per person.

So clearly if everybody produces in the way that we produce, the planet is going to get very hot very quickly and that is the decision that is the political one of how you get everybody involved because if you do not, it seems quite clear that we are going to have a planet that is hard for us all to live on.

Mr. WOLF. But you seem reluctant to say the word China. I ask again for the third time, how important is it to have China participating in whatever the solution may be when good and decent scientists come up and convince the world of this? How important is it for China to be an active participant?

Dr. SOLOMON. It is important for China to participate. It is also important for India in the long run to participate. It is because there are so many people in those parts of the world, it is important that we all do this together, I think. Otherwise, we are going to have a hot planet.

RESPONSIBILITY FOR EMISSIONS

Mr. WOLF. The last question is, would you agree or disagree with his comments where he says that countries importing Chinese goods should be responsible for the heat trapping gases released? As you are putting together a solution, would the country responsible be that taking the imports or would it be the country that is manufacturing?

Dr. SOLOMON. Well, I guess I do not see how the idea of charging the country who takes the goods would actually work. And I read the Post this morning also and that was a comment made there.

It is clearly a value judgment how you decide to implement any of these agreements. And I think that is where the science ends and the politics begin. My values are not any better than anybody else's, but I would hope I might have more to contribute on the science.

Mr. WOLF. Last question is, would it make sense to put together a high level group of international people, well respected of a lot of different political viewpoints to sort of come together and looking both at the science and as to how you then deal with it from an economic issue to make sure, because obviously if you are in Kenya, the poverty rate is so high versus if you are in, you know, London, it is in a different perspective, to begin to take the political out of it and begin to sort of develop a consensus for the world?

IPCC

Dr. SOLOMON. I think that is a good point. The United Nation's Framework Convention does try to do exactly what you are talking about. The Intergovernmental Panel on Climate Change helps provide the science information for that——

Mr. WOLF. But I think that there are many people that really do not believe the United Nations is very balanced. I mean, on votes with regard to human rights and religious freedom, generally the human rights and religious freedom fail.

China has pretty much intimidated the rest of the U.N. so they are doing nothing with regard to the genocide in Darfur. The U.N. has stood by and allowed the genocide to take place in Rwanda. So the U.N. is not really the group, I think. I am talking about an international group of respected outside of the U.N.

Dr. SOLOMON. Well, to some extent, that is the kind of thing that the Intergovernmental Panel on Climate Change already does and it does so under the auspices of the World Meteorological Organization. There is also U.N. involvement. So if you wanted to create an alternative entity that went completely out of the U.N., I suppose that would be an option.

Mr. WOLF. What are your thoughts about it?

Dr. SOLOMON. I think it is clear that IPCC has functioned quite independently over the years. I think we can point to the process that produces the reports that we have established as a useful one. It still will not answer the question of political action.

I honestly believe that separating the science basis for what you do from the value judgments that enter into a political decision is a healthy way to go. So I would frankly hesitate to have them all together as you are describing. I am not sure what the best political system or the nonscience part would be because that is outside of my expertise.

Mr. WOLF. Thank you, Doctor.

Thank you, Mr. Chairman.

Mr. MOLLOHAN. Thank you, Mr. Wolf.

Mr. Schiff.

Mr. SCHIFF. Thank you, Mr. Chairman.

RATE OF CLIMATE CHANGE

In recent months, some scientists have suggested based on new data that the climate is warming faster than the last IPCC report predicted. I know a full review has to await the IPCC reports again, but what do you think of the new data? Do you find it worrying? Is it too early to tell? What kind of research would bring more certainty to the projections?

Dr. SOLOMON. The types of things that are happening faster include evidence for melting on Greenland seems to be going faster, west Arctica also. There is evidence that the loss of ice from those places is becoming enhanced.

The rate at which carbon dioxide increased in the last few years has also been faster than before. And, finally, certainly a very key thing is that the retreat of sea ice in the Arctic has been faster, actually faster than anyone imagined and faster than the models predicted. So 2007 set a new record low for the extent of sea ice covering the Arctic Ocean.

The warming itself, the temperature changes on the ground have actually not been faster than previously. So I think there is a little bit of confusion among the different factors.

But I think they are all still, all those things taken together are still well within the type of totality that would justify saying there are aspects of the climate system that are changing faster and there are different time scales for things like the ice and the atmospheric temperatures.

So I think it is fair to say that we are certainly seeing many aspects of climate change that are happening faster than we expected, not all, but many.

Mr. SCHIFF. And what are the theories as to why we are seeing greater acceleration in the extent of the ice as opposed to, you mentioned, on land, the indications of warming are slower than projected? What are the theories about why that has been true?

OCEAN TEMPERATURES AND WARMING

Dr. SOLOMON. The ocean temperatures have a big role to play in holding back surface temperatures from warming worldwide. And we happen to be in a La Niña phase where the ocean in the Pacific is relatively cold. We are coming out of that now, so I think things will probably change in the coming year.

But when the ocean temperatures are cold, you also see temperatures on land that are cold, particularly in the Pacific sector, which is why our part of the world has been rather on the cold side.

Ice is responding in part I think to more the history of what temperatures have done. Particularly Greenland has a very slow time scale to melt. It just takes a long time. So you are seeing the accumulated impact of the many years of warm temperatures as far as the Greenland melt goes, whereas, let us say, for temperatures in the U.S., you are much more seeing a slight moderation of the warming trend because of the cold ocean temperatures.

TIPPING POINTS

Mr. SCHIFF. There has been a fair amount of discussion of the, you know, the tipping point. How indefinite is that science? I mean, how in terms of the melting of the ice caps, for example?

There is a cyclical phenomenon or a synergistic phenomenon where the more that melts, the more it increases the capacity to melt more. What are the limits of the science in that area in terms of determining, you know, when they may be gone for good?

Dr. SOLOMON. Yeah. The changes in Arctic sea ice certainly are one of the most dramatic things that has led me to start wondering about tipping points. I have been a little bit reluctant to do so for a long time because I am trying to be very balanced in the way I look at this problem.

But indeed the fact that sea ice has retreated so fast in the Arctic in 2007, 2008, many people actually thought it would recover in 2008, it did not. It was almost as low in 2008 as it was in 2007. So we may very well have pushed the Arctic past its tipping point into a different state in which it is going to be much warmer all the time and have much less ice every year. We will not know that yet for a few years, but I think it is clear that that signal sort of is emerging.

I think the other thing that is emerging is the way that changes in rainfall are probably being affected by climate change. The increasing evidence for drying in the Mediterranean and in the U.S. southwest and Australia is beginning to, I think, start to make a case for having perhaps passed the tipping point there as well.

ORBITING CARBON OBSERVATORY

Mr. SCHIFF. A number of the other witnesses we have had have talked about the loss we suffered with the failure to launch the orbiting carbon observatory. Do you have any thoughts in terms of is there another way to get that science or do we need to do a do-over?

Dr. SOLOMON. Wow, that is really a tough one. It would have been a great experiment. There is no doubt about that. I am, I think, less qualified than some of the people that are going to talk to you later in the week to evaluate the extent of that loss relative to other things that you are looking at. So I really would ask you to accept that I am just not expert in this.

Mr. SCHIFF. Thank you, Mr. Chairman.

Mr. MOLLOHAN. Thank you, Mr. Schiff.

Mr. Honda.

Mr. HONDA. Thank you, Mr. Chairman.

INTERNATIONAL COOPERATION

Dr. Solomon, thank you for being here. You are probably no stranger to being a witness to different committees.

Having heard a lot of questions and reading up on this issue of climate change, global warming, flash points and all that sort of stuff, moving our country to work with other countries and overcoming some of the barriers, obstacles to cooperation, and in the light of all the other issues that we throw out there, which seems to distract us sometimes from the main focus of getting together and start working together, if you were able to readjust our perceptions and some of our notions about ourselves and other countries in this whole debate, what are some of the things you would tell us to set aside or what are some of the things you would say to focus on for the benefit of the future? I know it is unscientific, but——

Dr. SOLOMON. No. It is actually——

Mr. HONDA [continuing]. You know, part of the thing about our human dynamics is that we allow certain things to get in our way in really addressing the human issues of us moving forward.

SCIENTIFIC CONSENSUS ON CLIMATE CHANGE

Dr. SOLOMON. I agree. It is a very important thing to consider the human issues. And if I may, I would like to say a few things that are perhaps more general.

And they are that I think we have gotten to the point where we are starting to lose sight of all the things we actually understand well about climate change.

Mr. HONDA. Yes.

Dr. SOLOMON. We have gotten so much into a shouting match about, you know, is west Antarctica going to melt tomorrow. And I am not suggesting for a minute we should not talk about risks. We absolutely should talk about risks and issues of high uncertainty.

But I also think we should not forget that there are a large number of things that we actually know very well, where we have measurements that show what is happening already. We know that there is very likely a human contribution to those changes. We understand the physics and we can predict the future.

When it comes to some of these risk issues like, you know, will the permafrost melt and the methane be released, very important issue, but we just cannot get our arms around it quantitatively.

So I think that if you are interested in overcoming barriers and bringing people together, developing a consensus that many people in the country can and the world can agree on, we should really be emphasizing a bit more all those aspects of climate change that are well understood, are very important, and we will do things to the planet that are unlike anything that has ever happened before.

And by that, I mean very quite rightly, Mr. Chairman, happened before while human beings were here because obviously we can go back three million years to a different planet that was, you know, we can go to Venus, too, and that is a different planet, but——

OBSTACLES TO INTERNATIONAL COOPERATION

Mr. HONDA. So when you say we, who are you talking about? Just folks on this country or are you talking about an inclusive we? If it is inclusive, what are the barriers of moving, coming together?

And then I guess the other question is, when we understand all these things to be true, the scientific and everything else, is that held by all parties like India and China, let alone ourselves?

So I guess I am moving towards what are some of the obstacles to arriving to yes, arriving to cooperation so that we can start developing common interests, trust, and, you know, without saying that, you know, these other human things do not exist. We still have to overcome it.

And I was just wondering what would you say to us? You all ought to be doing this or think about this or these are the barriers and let us get real, you know? What are some of those admonitions that you would have for us?

Dr. SOLOMON. Well, I think science is certainly a common basis that is valued in all countries. That is why IPCC has been, I think, so helpful to negotiators. It is not just Europe and the United States that are interested in understanding the science. Certainly China and India also want to know what the facts are. That gives you a basis to then discuss things.

I think, though, it is very clear that this problem has barriers to overcome that extend beyond science, that do involve human values. And as I said to Mr. Wolf, I think it is helpful to recognize where one starts and the other begins, where science stops and values begin when you try to design policies, I think is clearly one of the things that will help us.

There are major issues of what some people like to call international equity involved here because the developed countries have produced so much of the carbon that is already in the atmosphere. So it is now the turn of the developing countries and they would ask for some kind of system that is fair. And so jointly, we have to decide what we think is fair.

I think that the U.S. certainly has a lot to offer in terms of technology and technology transfer. I think those kinds of activities can really help because the more that we can assist other countries to emit less, to not be as inefficient in their use of energy as we once were because we have learned to be much more efficient over time, we can provide those technologies. That is the kind of thing that we can bring to the table in a useful way.

And certainly the efforts to produce new renewable energy sources, make them cheaper, make them more efficient, to the extent that we can share that with other countries will help to promote a sense of harmony and overcome the barriers as you called it.

I do not know if that is where you are trying to take this question, but——

Mr. HONDA. Through the Chair, it seems to me that there are a lot of things we do not know about the other countries and what their conditions and priorities are, but I suspect that they care about their children and their future.

I suspect that they have policies that they have not been able to implement as we have policies that we have not been able to implement or have oversight on.

But given all those things, it seems to me that we have people all around the world of good will who understand that we have to work together and that this word called cooperation is going to be a baseline and how do we get there. And I guess there has to be some give and take.

Israel and the Middle East have shown us that we can develop a process of confidence building mechanisms. We do not have one yet in this arena. It seems that we are worried about competition. We are worried about all this stuff that would be meaningless when we cannot breathe.

And so, all these things, these flash points we talk about, they all could happen at once like the permafrost and the emergence of CO_2 and methane in volumes that we will never be able to handle if we do not get in front of it and anticipate these things.

And these things do not occur linearly. They are all going to happen at once and if we do not as leadership demonstrate that willingness to do that, then who will? And so, the lack or failure of political leadership is not an option.

And so it seems that we have to sort of look for that common ground and look at diplomacy and, understand that all of us have different priorities and different conditions in our own country. We have one thing in common and we need to solve this problem together. And we could give and take and share.

And so I was looking for a response from a scientist who would speak not only from hard evidence but also from the human factor that really moves or stops progress.

Dr. SOLOMON. Well——

Mr. HONDA. And being real candid.

Dr. SOLOMON. Yeah.

Mr. HONDA. Because I do not want you to leave here and say I should have said.

Dr. SOLOMON. No. No. I see where you are going and I think I may have covered some parts of that earlier. I certainly agree that it is very clear that the whole world has to participate or let us say virtually the whole world has to participate in order for this to work.

One of the things that from a science point of view is particularly concerning to me actually is that just to stabilize carbon dioxide levels, we would have to reduce emissions by about 50 percent within the next few decades and by 80 percent not long after that just to stabilize it.

So the problem is that we are putting carbon dioxide into the atmosphere so much faster than nature can take it away, that we have completely overwhelmed the system. And so we have got to reduce it enormously.

How do we do that? How do even we, the United States, reduce by 80 percent let alone developing countries who are emitting very little now and would like to emit more, would, of course, like to develop? How do we as a whole planet reduce our emissions by 80 percent while 80 percent of the people on the planet continue to develop?

So that is the way I like to put it. But you will notice I always put it scientifically. I do not make emotional statements. I am really trying to keep the science separate from the issues of values and politics because I think that the more we do that, the better chance we have for all nations of actually agreeing on something.

But 80 percent is a big number when 80 percent of the people right now are very poor in the world.

Mr. HONDA. Last comment through the Chair, Mr. Chairman. When folks developed the nuclear bomb and things like that, they realized that they had a human responsibility to say something also in its use and sometimes they did not speak up quickly enough.

And so the opportunity to educate along the lines of human motivation and the things that make us human and the scientific information that makes us powerful, wisdom has to fall into there somewhere. And I guess the wisdom of your experience and insights is what I was looking for.

Thank you.

Mr. MOLLOHAN. Thank you, Mr. Honda.

Mr. Culberson.

Mr. CULBERSON. Thank you, Mr. Chairman.

REDUCTION OF EMISSIONS

Thank you, Professor Solomon, for coming all the way to Washington to be with us today and share your experience with us.

I wondered, if I could, to make sure I understood your testimony to Mr. Honda that in order to stabilize the CO_2 levels, just to stabilize them where they are today, that the world would have—is it the world would have to reduce CO_2 emissions by 50 percent or just the United States?

Dr. SOLOMON. The world.

Mr. CULBERSON. By 50 percent within what frame of time?

Dr. SOLOMON. A few decades at most.

Mr. CULBERSON. Meaning 20 years?

Dr. SOLOMON. At most.

Mr. CULBERSON. Thirty years? Twenty years. So by 2030?

Dr. SOLOMON. Roughly.

Mr. CULBERSON. And 80 percent by 2050?

Dr. SOLOMON. By 2050.

Mr. CULBERSON. What level of industrial production would that—the United States would need to return to a level of emissions that would be the equivalent of at what stage in our history?

Dr. SOLOMON. I do not know that number off the top of my head.

Mr. CULBERSON. That is a real important number.

Dr. SOLOMON. But, of course, the idea one might have is not to reduce our activity, but to do it in a different way using alternative energy sources, for example.

Mr. CULBERSON. Right. Well, then let me ask it this way. Assuming today we are consuming in the United States oil, petroleum products at a certain level that is 100 percent, considered today 100 percent, what level of today's level of consumption of oil would we have to reduce U.S. consumption by 2030 in order to achieve a 50 percent reduction in carbon emissions?

Dr. SOLOMON. I guess about 50 percent.

Mr. CULBERSON. Okay. And what level of production and petroleum consumption, petroleum products would we have to reduce by 2050, 80 percent?

Dr. SOLOMON. Again, the same figure. Of course, you could do more potentially with other types of reductions as well.

Mr. CULBERSON. Right.

Dr. SOLOMON. So, you know, you could reduce methane.

Mr. CULBERSON. Sure.

Dr. SOLOMON. You could reduce tropospheric ozone, you know.

Mr. CULBERSON. Right.

Dr. SOLOMON. There are other places where you could look for things that you could——

Mr. CULBERSON. And you include all petroleum products, not just—I mean, obviously the petrol chemical refining industry includes plastic, making plastics, almost everything in this room. Production levels would have to be reduced by 50 percent.

Dr. SOLOMON. You are certainly illustrating very well why this is an extremely difficult problem.

INTERNATIONAL CARBON DIOXIDE EMISSIONS

Mr. CULBERSON. Right. And Mr. Honda is exactly right that China, for example, has to participate. And I certainly wish they would. It would be wonderful if they would, but it is an objective fact that they will not and they have indicated they are not signing on to any carbon treaty. I have seen no indication.

I am looking at an article from the February 8th edition of the Journal of Science, an article on sustainable development, page 730. China has one of the largest coal reserves in the world and coal accounts for 67 percent of its primary energy use.

And China is currently bringing, Committee members, two additional coal fired power plants to the electric power grid every single week.

And by 2030, Dr. Solomon, the article concludes that China will be emitting as much carbon in 20 years as the entire world does today, but they will not sign on to any of the carbon treaties. So they are not helping at all.

In fact, this is an article from the February 9th edition, February 9, 2007 of the Journal of Science, page 812, talking about capturing carbon.

And they point out in the article, Mike, that the, quoting from the article, the major coal producers, Russia, China, and India, have been unwilling to sacrifice short-term economic growth. They just will not do it. So they are not going to participate——

Mr. HONDA. Would the gentleman yield for a second?

Mr. CULBERSON. Sure. You bet.

Mr. HONDA. Since you mentioned my name, it seems that Congress in its current form is willing to do that and we had a chance since the Kyoto Protocol and somehow as a nation, we refused to participate too. And there were reasons and motivations. But I do not think that that should hold us back. We should move forward.

Mr. CULBERSON. You know, Mike, you raise a good point.

Mr. HONDA. So thank you.

Mr. CULBERSON. No. You raise a good point, my friend, about the importance of getting the whole world to become involved. And I do hope the Chinese participate. You are exactly right, because the problem is so big and the Chinese emissions are so huge. Bringing two new coal fired power plants on line every week, that literally by the year 2030, China is going to be emitting as much carbon as the entire world.

So they are a vast producer of carbon dioxide, the largest in the world, right, Professor Solomon?

Dr. SOLOMON. Yes. Well, actually, maybe not. I think some of the Middle Eastern countries like——

Mr. CULBERSON. Bypassed them?

Dr. SOLOMON [continuing]. Qatar, United Arab Emirates.

CARBON SEQUESTRATION

Mr. CULBERSON. Right. And I am sure those guys are going to sign right up on Kyoto or whatever. I mean, they are going to be zero help.

I mean, we just have to assume, Mike, and you raise a good point, that these guys are not going to help much and that if we leave this burden entirely on the United States, I mean, we are talking about either radical—and everyone on the Committee knows how passionate I am about nano technology. I am convinced that nano is going to revolutionize everything that we touch.

And I think nano technology holds the promise of giving us a lot of the technology that you are referring to. And certainly the United States can make great strides.

But with the facts that the Chinese, the Indians, the Russians, the Middle Eastern countries are probably not going to help, they are not going to sacrifice economic growth, that is an objective reality, in order to help reduce carbon emissions.

Therefore, what I am leading you to, Dr. Solomon, is that we need to look to, in the meantime, if the goal is to reduce carbon, we need to look to technologies to sequester carbon is probably one of the better alternatives in the short term to remove carbon from the atmosphere in a significant way because then the United States is helping the entire planet; would you not agree?

Dr. SOLOMON. Yes. And let me just clarify. When I said the Emirates, I meant per capita.

Mr. CULBERSON. Okay.

Dr. SOLOMON. Not total.

Mr. CULBERSON. But it would be carbon——

Dr. SOLOMON. But, yeah.

Mr. CULBERSON. Carbon sequestration would be a good way to go, right?

Dr. SOLOMON. Carbon sequestration would in principle allow you to continue to burn coal and put the carbon back in the ground.

Mr. CULBERSON. And we need to work on the technologies, Mike. And, I mean, I am with you. We have got to work on this technology and nano technology literally will allow us to make, for example, the electric grid, to carry electricity ballistically without any resistance to store electricity.

Mr. Chairman, I can wrap this up in about two months, Mr. Chairman, if I have time. I have two minutes?

Mr. MOLLOHAN. Go ahead.

Mr. CULBERSON. Thank you, sir. You are very indulgent.

Mr. Mollohan is one of the most gracious Chairmen there is. He gives us plenty of time, particularly me. He gives me a lot of rope because I tend to go on a little bit. Thank you, guys, for the patience.

But I am leading somewhere specifically because NOAA, and I really admire the work that you all do, I in looking at carbon sequestration techniques, this same article in the February 9th, 2007 edition of Science points out that the uptake of carbon dioxide by the ocean combined, this is a direct quote, Mike, combined with dissolution of marine carbonate will absorb 90 percent of the carbon released by human activities.

You would agree with that? The ocean is the largest single carbon sink on the planet?

Dr. SOLOMON. In the long run, yes.

Mr. CULBERSON. Right. And that a cubic yard of mid ocean water contains less life as a general rule than a cubic yard of Sahara Desert sand. That is why the ocean is so clear.

And that whenever there is a dust storm over Africa, the way, you know, the good Lord has designed the earth to balance these things out, the dust storm blows dust over the ocean. The plankton bloom and there is vast reductions in carbon dioxide, tremendous emissions of oxygen.

And what I am driving you towards is that is it not true that we have seen that there is significant potential in fertilizing the ocean with iron to enhance the growth of phytoplankton as a way to sequester carbon rather dramatically; is it not? And Woods Hole Institute has been one of the leaders in this research.

Dr. SOLOMON. There have been some studies of that effect. You are quite right. It is possible to do it. What is not completely clear is how long you keep the carbon in the ocean doing it that way. To what extent it comes right back out is one question. Another one is how much you also get of other things like N20, nitrous oxide.

Mr. CULBERSON. Right. There has not been much research. Not much research has been done.

Dr. SOLOMON. It is certainly a possibility.

Mr. CULBERSON. Right.

Dr. SOLOMON. But it is not one that is proven.

Mr. CULBERSON. My time is so limited, I am going to close with another question and I hope I get a second chance.

But, Mr. Chairman, I wanted to ask Dr. Solomon because our Committee, something I brought to the Committee's attention, and I would like to pursue, Mr. Chairman, with the Committee's support, that we direct some funding to NOAA for you to do the research to tell us what would be necessary in terms of sequestering carbon in the ocean using iron fertilization and in particular nano particles of iron oxide because all the research has been done using iron sulfate and that creates acid.

And the nano particles of iron oxide would be taken up much more readily by the phytoplankton and the iron oxide would not create an acid situation because, of course, the absorption of carbon by the ocean raises the acidity level and, therefore, if you use iron oxide, you would not have the acidity problem.

So would you, if I could, and my final question, my Chairman is gracious with the time, would you be agreeable to and could you do that research if this Committee directed some funding to NOAA for the specific purpose of telling us what, how much would be, what type of iron fertilization would be the best, how much carbon could the oceans take up, and what the side effects would be?

Dr. SOLOMON. Geo engineering is certainly one of the things that people are doing research on. Iron fertilization is one option. There are other options that personally I think ought to be pursued as well. You are exactly right.

Mr. CULBERSON. Personally, I am not asking your personal opinion. I am asking could NOAA do the research?

Dr. SOLOMON. I really cannot speak to that. I certainly could not do it personally.

Mr. CULBERSON. Oh, you could not?

Dr. SOLOMON. It is not what I do. It is not what I do as an individual scientist.

Mr. CULBERSON. Your focus is not carbon sequestration?

Dr. SOLOMON. That is right.

Mr. CULBERSON. Okay. But NOAA is certainly capable of doing the research. You have got other divisions.

Dr. SOLOMON. I imagine NOAA has some capability in that area as do others.

Mr. CULBERSON. Thank you very much, Mr. Chairman, for your indulgence.

Mr. MOLLOHAN. Thank you, Mr. Culberson.

Mr. Fattah.

Mr. FATTAH. Thank you, Mr. Chairman, and thank you for having this hearing.

First of all, welcome again.

LOCAL EFFECTS OF RENEWABLE ENERGY

You talked a little bit in your testimony about reengineering and the concern as we move aggressively in terms of, hopefully aggressively in terms of renewable energy, wind and solar, about perhaps that there are issues still to be looked at in terms of the impact of wind power particularly and the uses of wind and whether there would be climate changes or issues to be concerned about.

Could you expound on that a little bit?

Dr. SOLOMON. Yes. It is very interesting that just the presence of the wind turbines when you have a lot of them in a given area, you create a lot of turbulence. And there are environments in which local meteorological changes have been observed like fog, you know, and changes in the stability of the atmosphere are pretty serious issues.

So I am not suggesting that we should not pursue those, but there are things that would need to be resolved in choosing the places where it could be done without disturbing the environment too much.

Mr. FATTAH. Yes. I am a big fan of proceeding aggressively in this direction but obviously we do not want to cause more harm as we go forward. So I was very interested. Now, is there research that is being done now, looking into the question of the impact and how site locations might be best? I mean, for instance, Texas is moving aggressively in terms of wind generation and there are other places throughout the country. Is there now data informing those decisions as we speak? Or is this a new area of research that we need to invest in?

Dr. SOLOMON. It is a new area of work. I think there is more and more research directed at trying to understand this issue in various parts of the country, not only for wind but also for other activities, like biofuel, and what the water demand to do biofuels is, how it could be met. So I think in all the areas of mitigation science there is a similar need for research to understand the environmental consequences of any of those mitigation activities. And yes, it is an area people have worked on for a long time but clearly more and more people are starting to work on these questions now.

One of the big problems we have is actually not having models that have enough spatial resolution to really get down to the level that you need to get to to really study a lot of these things. And people are developing ways to get around that, basically, by using sort of nested approaches and things like that. But it is a very active research area.

Mr. FATTAH. Active at NOAA? Or over at the Department of Energy? Or where?

Dr. SOLOMON. Both, I think it is fair to say both.

Mr. FATTAH. And is there cross fertilization in this research effort?

Dr. SOLOMON. Yes. I think there is an emerging effort at cross fertilization. And, again, because it is a new area there are not a lot of people working on it yet. But I think there will be more and more. It is one of those things that has to develop.

Mr. FATTAH. Well, I want to, and you also mentioned this notion of reengineering relative. Can you talk a little bit about the general, beyond when, the other areas that need to be looked at in terms of the notion around reengineering? Because you mentioned solar, you mentioned sun redirection, and so on.

EFFECTS OF ALTERNATIVE ENERGY DEVELOPMENT

Dr. SOLOMON. Yes. I mean, I think we do not really know. If we begin to build solar rays so massive that they would, they would be working to provide the enormous demand for energy. So that energy would be going into the solar system rather than into the ground, as it would otherwise be doing. The local meteorological impacts of that, I think, are something to just take a careful look at and make sure it is understood. I think from the global point of view it is, you know, it is clear that it is not a huge problem. But locally, you know, when you are concentrating the energy, yes, yes. So that is one of the sorts of things.

I think the biofuels we have a lot of questions. I mean, one obvious one is when you begin to use the available land to grow biofuels instead of food what are the impacts on food security are a serious issue. But the other one is what about the demand for water? And another one is what about the emissions of nitrous oxide, if you are going to fertilize all of that stuff. There are side gases that can be released. So the whole question of scientific understanding of the side effects, if you want to call them that, of all of these alternative energy approaches are, I think, merit our attention.

INTERNATIONAL COOPERATION IN CLIMATE RESEARCH

Mr. FATTAH. Now lastly, you are connected with a number of the international scientific organizations, London, France. To what degree internationally is there collaboration and around these types of research points?

Dr. SOLOMON. There is actually a lot of collaboration internationally. There obviously could be more and I think that pulling in the developing countries more and more is something that everyone would like to do in research and in the scientific endeavor in general. But the number of joint projects, joint experiments, joint satellites, all of those things, has gone up enormously in my career in science, anyway. And I think that is a very encouraging thing.

Mr. FATTAH. And last question, so there has been no, like, post–9/11 challenges relative to research related work that you are involved in, in terms of sharing of information and the like?

Dr. SOLOMON. Well, I mean, the world has gotten a little bit harder to get around in in the post-9/11 era for all of us, as we know. And it has occasionally caused some problems. I think it is not at a level that is really impeding the kind of science communication that we need to have. And I very much hope that continues.

Mr. FATTAH. Thank you, Mr. Chairman.

ICE SHEET MELTING AND SEA LEVEL RISE

Mr. MOLLOHAN. Thank you, Mr. Fattah. Just to get a clear, crisper answer on the record to the question that I was asking before yielding, what is the probability that the West Antarctic Ice Sheet could float or melt, or that the Greenland Ice Sheet could melt by 2050 and by 2100? And what would be the consequence of the sea level rise?

Dr. SOLOMON. I can answer the second part of the question better than the first part. If West Antarctic were to completely melt it would produce about five meters, or about fifteen feet, of sea level rise. If Greenland were to completely melt it would produce about seven meters, or about twenty-one feet of sea level rise. So those are enormous numbers.

We have not got the science to tell you what the probability of that happening by 2050 or 2100 is in either case. I cannot give you a probability. We have reasons to believe that probability is small. But it is not zero, and we do not know what it is.

Mr. MOLLOHAN. Well, the phenomena is in process, is it not? The melting of the West Antarctic Ice Sheet and the Greenland Ice Sheet?

Dr. SOLOMON. We see local, rapid, and very impressive movement of ice in both of those places. But it is local. And we just do not know how much more we could get integrated over the whole ice sheet as the planet gets warmer. I guess——

Mr. MOLLOHAN. What does that mean? Say that again?

Dr. SOLOMON. We see effects in particular places but it is very hard to extrapolate that to know what is going to happen over the size of the Greenland Ice Sheet, which is an enormous chunk of ice. But we just do not know enough to extrapolate from our local measurements to Greenland as a whole.

We do know that the last time the Earth was warm, warmer than it is today, which was about 130,000 years ago, the polar regions were about three to five degrees warmer then than they are now. Which is about what they might get to by, say, late century. Two to four meters of sea level rise occurred. So sea level rise rose, went up by about that level. We do not know how fast that happened. It may have taken many hundreds of years or it may have been fast. We just do not know. But we do know that when the Arctic was warm and the Antarctic was warm 130,000 years ago sea level was two to four meters higher than it is today.

REGIONAL CLIMATE CHANGE

Mr. MOLLOHAN. Looking at a recent consequence of climate change, in assessing ozone depletion the science community started with global average predictions. But experimental evidence, some of it from your own measurements in Antarctica, I am advised, led to a focus on a regional change, the ozone hole. In assessing climate change, what environmental factors should be viewed regionally and what globally?

Dr. SOLOMON. The ozone hole, I think, was a compelling thing to many people because it allowed them to see a pattern of change. Not just a global change but a regional change, as you say. And I think some of the factors in climate change that we now are seeing in a very useful, regional way are, particularly those having to do with rainfall where although we have a fairly small change in rainfall globally averaged there is a pattern where some places get drier and other places get wetter. And we are seeing that both in data and in models. It is, I think, also well understood from the point of view of the way the physics work. It would be nice if, you know, the dry places got wetter and the wet places got drier. But unfortunately it is exactly the opposite. So it is particularly a place where the regional changes are very important. And our own Southwest U.S. is one of the places where we are beginning to see this. So rainfall is a very big one.

The other issue, of course, is the Arctic where we expect to see the largest warming and we are seeing the largest warming. And we are seeing massive retreat of the sea ice extent, which is even faster than we expected. So the Arctic will be becoming more and more a different world. It is causing things like coastal erosion, because the absence of the sea ice means that the beach is no longer as protected as it used to be. So there are big problems with coastal erosion in Greenland, sorry in Alaska, I meant to say.

The other thing that I think is very interesting from a point of view of regional change is snow pack. The nice thing about ice and snow is it is either ice and snow or it is not. So it is a very clear threshold. And because temperatures are warmer on mountain ranges all around the world what we are seeing is that on average it does not snow as much at low altitudes. So the snow line is moving up. And the amount of snow sequestered on the mountain at the end of the winter is reducing. So it is not as available to melt and provide water the following summer. And that sort of thing in California, in the Cascades, in the Rockies, in Europe in the Alps, is beginning to be a very, very clear regional signature of climate change. So those are some of what I view as the really clear regional patterns of climate change that are of concern.

RESPONSE OF GREENHOUSE GASES TO REDUCTIONS

Mr. MOLLOHAN. Emissions of chlorofluoromethanes, the major contributors to ozone depletion, have been banned for many years. But I am advised that the ozone hole still occurs and full recovery of the stratospheric ozone layer is decades away. Well, once human emissions of greenhouse gases from whatever country or from whatever source are greatly reduced, how rapidly will climate change respond?

Dr. SOLOMON. It is very much dependent on the type of gas that is reduced and how long its lifetime in the atmosphere is. There are some greenhouse gases that are increasing because of human activities that do not live very long in the atmosphere, and a good example of that is tropospheric ozone. If you want to call it smog you can, but it is more of a global smog. That stuff only lives a short time. So if we were to stop the emissions that were causing it then the smog would go away fairly quickly and the climate would respond fairly quickly, time scale of a few years or so.

In the case of methane the lifetime is about ten years. So, again, if you reduced emissions, and we have seen some evidence from reduced emissions from things like mining, activities like mining where people are starting to tighten up those activities, that should, in principle, give you a climate response rather quickly, time scale of a decade or so.

Carbon dioxide, on the other hand, lives a very long time in our atmosphere. Most of it lives longer than a hundred years. There is a fraction that gets removed quickly, but that is a small fraction. Most of it hangs around for a very long time. And in fact, some of it will still be here even in a thousand years. So about 20 percent, actually, of what we are producing of carbon dioxide will still be in the atmosphere a thousand years from now, which is a long time.

The climate changes from carbon dioxide actually only, well, let me see if I can explain this. Carbon dioxide has a unique effect in climate because not only does it take a long time for it to go away, the time scale at which it is going away is matched very closely by the time scale in which the climate can actually respond. So what ends up happening is that the temperatures are essentially irreversible. The increases in temperature are essentially irreversible once you have cranked up the carbon dioxide. You can crank the carbon dioxide back down, but the warming actually remains nearly constant for about a thousand years. It is essentially irreversible. And the reason is because there is a bit of a time lag associated with the oceans. That is the fundamental problem here. And it causes the temperature that we get as carbon dioxide increases to be a little bit less than what its equilibrium value would be. And then it causes the temperatures to stay just about where you got them to for many hundreds of years. So the two things work together. The oceans and the carbon removal work together to keep the temperatures almost constant for about a thousand years or more. So we can only crank that dial one way. We have to decide how far we want to crank it.

Mr. MOLLOHAN. Well, you may have spoken to my next question but let me ask it. In the context of different nations' responsibility for climate change Dr. James Hansen has pointed out that the excess carbon dioxide in the atmosphere today has come primarily from countries that have been industrialized for decades or more, and that the full effects of these past emissions have yet to occur. Can you explain this and to what extent did you just explain it in your last answer?

Dr. SOLOMON. That is related to that thing I just discussed. Even if we kept carbon dioxide and all of the other climate forcing factors constant, the atmosphere would continue to warm by about a half to .6 degrees Celsius, or let us say almost a degree Fahrenheit. And most of that would happen in the next century. And the reason is that right now the ocean in a sense is lagging the atmosphere. You can kind of imagine that, you know, air that absorbs a certain amount of heat. But the ocean being much colder is lagging behind. If we kept the concentration of everything constant the ocean would have a chance to catch up, and then the atmosphere would in turn also get a little bit warmer. So that is the factor that Hansen was referring to. And that also has a role to play in the irreversible climate change that I was talking about before. So, yes, this is linked to my previous answer. But it is about a degree of further warming.

Mr. MOLLOHAN. Okay. Thank you, doctor. Mr. Wolf.

DEFORESTATION

Mr. WOLF. Thank you, Mr. Chairman. Two questions, doctor. How significant in impact is clear cutting in Brazil and around? And also here in the United States. And is there a formal program with regard to planting of trees, encouraging, and formal programs that can sort of ameliorate that, or balance it out, or whatever? But can you talk about the impact of clear cutting? How much that is making a contribution, and also how do you deal with that other than just stopping it? But can you make up the difference?

Dr. SOLOMON. Deforestation accounts for something like 15 to 20 percent of the total carbon emissions, and the rest of from fossil fuel burning.

Mr. WOLF. And where is most of that clear cutting being done?

Dr. SOLOMON. Mostly in places like Brazil. A lot of it is in South America. Some is in Indonesia. I do not have off the top of my head the full list but those are the main ones.

DEFORESTATION & CLIMATE CHANGE

Mr. WOLF. And by having an aggressive program of planting trees, wherever it may very well be around the world, how significant can that be with regard to——

Dr. SOLOMON. Certainly——

Mr. WOLF. Is there one for one? Or is it a mature tree versus a tree that is only five years old? Is there any kind of balance there?

Dr. SOLOMON. Well, that is a good question. I am not sure I can give you a very quantitative answer on it. Certainly avoiding deforestation, or replanting, are really two different things.

Mr. WOLF. Right.

Dr. SOLOMON. Right? So replanting would slowly give you a significant effect. If we were to plant as much as we possibly could I think some estimates have it that we could offset I think about 10 to 15 percent of today's carbon emissions. But I would have to check that to be absolutely sure.

Mr. WOLF. I guess what, I was not clear, too, like out in Oregon and places like that, for every tree they cut they generally plant one or two or three, Weyerhaeuser, the companies, whatever it may be. How significant is it, such as a tree that is cut, say at, a twenty-five year old tree, versus putting several new seedlings in that are one or two years old. Is there a, is the fact that it is growing whereas the other has kind of stopped its growing, making a different insofar as the impact? Or is it, how does that balance out? And maybe you cannot answer that, maybe you should just check for the record. But do you follow what I am saying?

We put a new seedling in, okay, we have a Christmas tree farm and we cut the tree, the trees are beginning to stop growing at a certain age. It still is growing but not to the spurt that you get, versus we put brand new seedlings in, they grow about a foot a year. The growth is more aggressive, there are more trees, but they are smaller. Is there a trade off there? Or does that have a balance? Does that make, have——

Dr. SOLOMON. Yes. The young trees grow faster, exactly, than the old trees.

Mr. WOLF. Right. And do they make a greater impact on——

Dr. SOLOMON. So, yes, the more you replant the more you can actually have a positive impact.

Mr. WOLF. Yes, but——

Dr. SOLOMON. But it depends on what happens to the wood in the old tree.

Mr. WOLF. Right. I understand that. But, I mean, how can I put this, one for one, is the fact that the tree is growing aggressively having a better impact on global warming than a tree that is mature, and old, and is not growing very, very much at all? Is there a balance, a trade off, a difference? Do you get more with that new seedling after five years than you do with a tree that is thirty-five years old?

Dr. SOLOMON. Sure. In principle, the young trees certainly grow faster. And there are varieties of trees that are the fastest growing that are used in places that are trying to do reforestation projects to help the carbon budget.

Mr. WOLF. Now is that being looked at? Are there any programs down in, say, Brazil and Indonesia that are aggressively looking at that?

Dr. SOLOMON. Yes. The danger, of course, is that you have to decide how much you want to encourage deforestation of old growth forests in order to——

Mr. WOLF. Well, I was not thinking of cutting one for one. I was thinking taking areas that have now been plundered and stripped. I mean, we have strip mines down in West Virginia and in Pennsylvania that they are coming in a putting trees in that are making a tremendous, positive difference. I mean, looking to reclaim, if you will.

Dr. SOLOMON. Yes. Reforestation is certainly a very active area that is being looked at.

Mr. WOLF. I mean, is that one of the recommendations that the international panels are looking at? Or is that just sort of an afterthought? Or is it something aggressively people are saying to do, to push? Are there formal programs pushing that?

Dr. SOLOMON. IPCC does not recommend anything and we do try to avoid pushing anything. But there are numbers in our reports for how much you can actually achieve with that kind of an approach. It is one of several options that can be a good one.

ETHANOL

Mr. WOLF. Okay. A last issue is what impact do you see this having on the world, you know, ethanol? Some are saying it is 10 percent, and would like to go to 15. What impact does all this have on the issue of hunger in and around the world? Do you see this taking place, say, five, ten, fifteen, twenty years from now?

Dr. SOLOMON. Yes, it is a big issue how much food production is potentially going to be affected by increases in biofuels.

Mr. WOLF. And how about the climate issue, too? What impact is that going to have? You talked about drought earlier, on food supply around the world in ten, fifteen, twenty years? I mean, we have had a famine in Ethiopia in 1984 and the world was electrified. The famine came again in the mid-nineties. I mean, they have not done very much. They have not done very much reforestation. They have done very, very little. So people have died because of that. What impact will this have on particularly third world countries and the poor with regard to this, enough food supply?

Dr. SOLOMON. Clearly, it is going to make it more difficult to grow food in those regions that are going to see less rainfall. And especially developing countries where all of the agriculture is rain fed, in Africa in particular. They do not have irrigation like what we have. So climate change is projected to have a very significant impact on the world's ability to grow food, particularly in the developing world.

Mr. WOLF. Okay. Okay, thank you, Mr. Chairman. Thank you.

Mr. MOLLOHAN. Thank you, Mr. Wolf. Mr. Serrano.

Mr. SERRANO. Thank you, Mr. Chairman. Sorry I am late. I was attending another hearing, and Happy St. Patrick's to all. Doctor, we have an unwritten rule around here and a rule in the House, where we usually do not speak to the audience. We speak to our witnesses and to each other. Sometimes we do not listen but that is what we try to do. But I cannot help but notice the number of young people that are in this room right now behind you. And it seems that when I was their age I do not remember this many ice storms, or floods, or these kinds of things happening which are so horrible, not only in our country but throughout the world. My question to you is, was it always this bad but we did not have CNN, and Fox, and the internet to tell me about it in thirty seconds after it happened, or has it gotten worse? Or is it a combination of both?

SEVERE WEATHER & CLIMATE

Dr. SOLOMON. I would say it is a bit of a combination of both. There are some of these things that happen very infrequently, and they are always impressive when they do, so there is always a temptation to say, "Uh-huh, that must be global warming," which is probably not always correct. But the example you gave of flooding I think is a particularly interesting one. We are seeing clearly that we are seeing more rain falling as heavy rain now compared to light rain than we used to see. We are seeing that worldwide. We understand it physically. It is exactly what we expect. So instead of having, you know, just a little bit of light rain, the same amount of moisture might fall but more of it is going to fall in those big, heavy events. That, obviously, will contribute to flooding. So I think that it is pretty clear that that is an example of the kind of thing that you can hold up and say, "Yes, we understand that. That should be happening and we know why it is."

Other things are a lot more difficult to say. Not all kinds of extreme events are due to climate change. But heat waves, another good example where we are seeing more frequent and more intense heat waves. So there are certainly many different kinds of climate change that are different now than they were for the young people in this room.

Mr. SERRANO. I remember something interesting. I was interviewed recently by PBS and they asked me what is the greatest accomplishment of the Puerto Rican community in New York City, and I said adjusting to the weather. And it threw them for a loop. And I remember in March of 1950 arriving in New York and it seemed to me that it stayed around, it stayed colder longer in New York City than it stays now. Or at least it felt that way. Yet, it seems that we have less, not as many frequent snowfalls but when they fall, they fall with an intensity that they did not fall before. Now, again, am I imagining this? Is this CBS and CNN, you know, pounding it into my head for 24/7? Or has that also changed?

And my last question has to do with an ongoing gag in these committees, how long before Congressman Serrano mentions Cuba or Puerto Rico? And the question is, are we looking at a day when climate change will not have us know areas as we know them now? The tropics will become colder, and the north will become warmer?

Dr. SOLOMON. The last one is pretty easy. I think there is no evidence that the tropics will become colder.

Mr. SERRANO. No evidence?

Dr. SOLOMON. Everybody is going to become warmer. But the high latitudes will become warmer to a greater degree than the low latitudes. So tropical places will warm, just not as much as higher latitudes. And the highest latitudes in the Arctic will warm most of all.

Your other question was about more snow and more heavy snow. That kind of goes along with what I said about rainfall. I said rainfall, but I really meant precipitation. And you are right. There is every reason to believe that we are seeing on average more snowfall and more heavy snowfall, particularly in the Arctic. I think it is a little harder to say for New York but it is probably just emerging from the noise, from the variability.

FUTURE GENERATIONS

Mr. SERRANO. Yes. Do I have a few seconds here, Mr. Chairman? And my last comment or question has to do with the folks that are in the room, and it has to do, according to my question here, with third graders. And you might have answered this already. If you walked into a room, a classroom of third graders, or you went into some of the classrooms where some of these younger people may be attending these days, without the gloom and doom scenario that you do not want to present, nobody wants to present, what would you tell them about what is in store for the future? And I know this is an unfair question, in twenty-five words or less to tell me, you know, what would you tell them they can do?

Dr. SOLOMON. Well, I guess the first thing that I would tell them is that their world will be different from the world that any previous generation had experienced, because their climate will have been changed by human beings. Sometimes when I am making a joke I tell them that this is a really good thing you can blame on your parents, and they like that. But I think the real interesting thing here is that this is such a challenge to society. It is such a challenge for us as a world, as a planet, to figure out what we are going to do about this, that they do have an opportunity to be part of a change which will go down in history as one of the most important things that we ever decided to do. One way or the other. We are either going to decide to keep emitting at current rates, and make the future world dramatically different from the past, or we are going to make some decisions that will slow it down and possibly stop it. And that is an incredibly important set of decisions.

When you think about the fact that they geography of the planet that we see right there on the wall behind us will be potentially made different by the actions that we are doing right now. We will either bury or not bury a lot of islands. We will change the shape of Florida, or not change the shape of Florida. We will——

Mr. SERRANO. That is inviting to some people, you know, but——

Dr. SOLOMON. Well, I thought Florida might be of interest to you, sir.

Mr. MOLLOHAN. What happens to Puerto Rico?

Ms. SOLOMON. Probably, it depends on, you know, it is not a pretty picture for island nations. And, you know, the drought issue, and the accompanying desertification. If you look at that map and you see the, you know, the Sahara, and you think about what is really happening is the Sahara is expanding northward into Southern Europe. That is what I mean when I say those places are going to get drier. And you look at our country, Southwest U.S. will begin to look like, you know, the middle of Mexico, the very dry regions of Mexico. So it is, it is a change the likes of which the world has never seen.

Mr. SERRANO. Mr. Chairman, thank you. And just a thought. You know, we spend a lot of time in this country talking to other countries about how they should behave in terms of their form of government. And that is okay for us to do that. But I wonder if we should not evoke just as much energy talking to other countries about trees, and about water, and about the air. Because at the end of the day it does not matter if you are a socialist, a communist, or a Democrat. If the world looks the way the doctor is telling us the bigger issue may be the world and not the form of government it has within that country. Thank you.

Mr. MOLLOHAN. Thank you, Mr. Serrano. Mr. Honda.

CLIMATE CHANGE METRICS

Mr. HONDA. Thank you, Mr. Chairman. We touched a little bit on flashpoints. And the discussion about the impact of the possibility of the permafrost softening up, the impact of the bacteria action creating CO_2 and methane, not knowing when that happens, decoralization, seeing the corals of the ocean now disappearing because of other kinds of activities. And seeing all this, anticipating all of these things happening, how would we as a nation and as a globe create a calendar of events, looking at checkpoints, milestones, and coupling that with the lack of progress or progress? Is there a way that we can measure and have a metric going on that will show us the impact of every policy that we do? And its dynamics on this thing we call global warming, or climate change? Because none of this happens in a linear fashion, you know? We all impact something in another way.

And one thing that we have not talked about is diseases. How the impact of diseases will be enhanced, or will occur in a greater, maybe in an epidemic fashion if we do not pay attention to this global change? And the change of our environment to a warmer climate? What kinds of metrics should we be looking at to develop so that the sense of a tick, tick, tick time bomb in our own beings will affect our behavior and our sense of urgency?

Dr. SOLOMON. Well, you mentioned coral reefs and they are also one of the things that I think is a good metric. We are already seeing damage to coral reefs. We will probably see a lot more in coming years. The issue of ocean acidification is a big issue for coral reefs as well as temperature changes. So as the carbon dioxide acidifies the ocean the coral reefs are getting hit from all sides. The way that is affecting other marine factors is also something that I think is a metric we ought to be looking at. Things like the viability of fish, the populations of fish and how they are likely to be affected.

Human disease is a really important factor as well. I am not sure there is an easy metric there. But the one that seems to be the most obvious is that because of increases heavy rainfall there are increases in experiences of cholera and other waterborne diseases in the developing world. So those are the kinds of things that certainly are of great importance to look at.

You know, the difficulty in a sense with climate change is that the wider you look the more you find. There are so many different things. In my own part of the world in Colorado one of the things that really concerns me are the changes that we are seeing in our pine forests, which are beginning to be attacked by pine beetles in a way that seems to be more intense than it ever was before. It is hard to know because we have seen pine beetle outbreaks in Colorado before. But we are seeing it much more extensively now. And in British Columbia, just a little to our north, I think it is more clear that the pine beetle devastation there is being caused by global warming.

So almost wherever you look you can find a metric that will matter to the people who live in that place. And it is really the diversity of effects in climate that I think makes it hard for some people to get their minds around. It is hard to find that universal, single factor. But I guess again I keep coming back to it. If I had to name the ones that concerned me the most it is part, number one is rainfall, and the way that that is affecting our ability to grow food, and the way it is affecting ecosystems is probably going to be huge. And I think we are already seeing it. You mentioned coral reefs. I would maybe broaden that to biodiversity hotspots in general around the world. And that could include the pine beetle, for example. Human disease is another one but much more difficult to quantify.

Mr. HONDA. Thank you.

Mr. MOLLOHAN. Thank you, Mr. Honda. Mr. Culberson.

SEA LEVEL RISE AND ICE SHEET MELTING

Mr. CULBERSON. Thank you, Mr. Chairman. And Dr. Solomon, forgive me for interrupting you earlier. My time is so limited that I have to try to bore in quickly. You testified a moment ago, I thought I heard you say that the, if the Greenland Ice Sheet were to melt entirely the ocean levels would rise by how many meters?

Dr. SOLOMON. Seven meters.

Mr. CULBERSON. I am sorry?

Dr. SOLOMON. Seven.

Mr. CULBERSON. Seven meters. And Antarctic was fifteen meters?

Dr. SOLOMON. Five.

Mr. CULBERSON. I am sorry, five. Okay, five, Antarctic. All right. And the erosion, or reduction in the Greenland and West Antarctic Ice Sheet cannot be attributed entirely to global warming. There is an interesting article I picked up in the October 3, 2008 of Science that points out that the, they have got, quoting from the article, "two new studies point to random wind induced circulation changes in the ocean, not global warming, as the dominant cause of the recent ice losses in Greenland and the West Antarctic Ice Sheet." The scientists doing the study said conclusively, quoting from the article, "In Greenland, at least, you are going to have trouble blaming this on global warming, says glaciologist Richard Alley of Pennsylvania State University in State College." He points out in the article that the losses long puzzle glaciologists because the atmosphere of the glaciers did not seem to have warmed enough to trigger the ice losses and that they went back and looked at the records of fisheries researchers. They had recorded bottom temperatures off Southwest Greenland from 1991 to 2006. And they traced the influx of, the ocean apparently became much warmer, Mr. Chairman, during this time frame. And the scientists traced the influx of ocean warmth back to the atmosphere over the North Atlantic. And quoting from the article again, "An abrupt weakening of winds due to a natural phenomenon known as the North Atlantic Oscillation drove more water from the Irminger Sea near Iceland, around the tip of Greenland, up onto the shelf and under the ice. And that triggered the ice loss. So we cannot, is that not true? These studies are valid?

Dr. SOLOMON. I do not disagree with any of that. That is why——

Mr. CULBERSON. Okay. So you cannot attribute the loss in ice in Greenland, in particular, to global warming?

Dr. SOLOMON. That is why we did not put a number for how much further sea level rise you might see in 2100 due to the Greenland Ice Sheet in the report.

Mr. CULBERSON. Right. I just want to be sure——

Dr. SOLOMON. That is exactly——

Mr. CULBERSON [continuing]. Because your answer to the Chairman's question——

Mr. FATTAH. Would you let the witness finish her answer?

Mr. CULBERSON. I am sorry, certainly. Yes, ma'am?

Dr. SOLOMON. I do not disagree with any of that. As I said, it is really hard to extrapolate from what we are seeing now to know how much sea level rise from the whole ice sheet to expect. I fully agree that that is an issue.

Mr. CULBERSON. Right. But I want to make sure that the Chairman and the Committee, because your answer to the Chairman was that it, as I understood your answer, was that the loss of ice in the Greenland Ice Sheet was due to global warming. And I just want to make sure that the Chairman and the Committee understand that it is, in the case of Greenland in particular, they have shown conclusively it is wind induced oscillations.

Dr. SOLOMON. I think——

Mr. CULBERSON. Driving warmer water up underneath the sheet.

Dr. SOLOMON. I think there is good evidence that some of it is due to global warming. There is good evidence, also, that in the last few years the wind system was unusual and probably contributed to some of the losses.

Mr. CULBERSON. Right.

Dr. SOLOMON. So I think it is a bit of both.

Mr. CULBERSON. Right. I just think it is important for clarification, Mr. Chairman, that we do not attribute it entirely to, and there is no question CO_2 is at, as the, another interesting article I picked up points out, and this is from the October 24, 2004 Journal of Science, that current atmospheric CO_2 levels, Mr. Chairman, are higher than they have been for the last full 130,000 years. I am not diminishing that at all, Mr. Fattah and Mr. Chairman, and Dr. Solomon. It is higher than it has been for tens of millions of years. And over the next 100 years, the article states, without substantial changes in energy technology or economic development atmospheric CO_2 concentrations will rise to 800 to 1000 parts per million, as you have testified. This rise, quoting from the article, Mr. Chairman, "this rise represents a spectacular, uncontrolled experiment that humans are performing on the earth," and that the paleoclimate record may provide the best guess as to what may happen as a result.

OTHER GREENHOUSE GASES

Very briefly, they point out at the end of the Eocene era 50 million years ago there were palm trees growing in Wyoming, and there was no permanent ice cap, ice sheets at either pole. And that this is astonishing, I think it says in here, yes, "deep water ocean temperatures more than ten degrees warmer than today." So there is no question what we are seeing today is an unprecedented increase in the levels of CO_2, and clearly CO_2 is the primary source, the primary greenhouse gas. However, it is not the only greenhouse gas. Is that not correct? I mean, methane also has a pretty dramatic impact in increasing atmospheric temperatures, does it not? Methane?

Dr. SOLOMON. Methane's increase is about, contributing about a third as much as carbon dioxide to today's warming.

Mr. CULBERSON. Right. I think they call it the reflective, the radiative forcing of non-greenhouse gases contribute an additional one watt per square meter of temperature increase compared to CO_2, which is 1.6. So you are exactly right. It is about a third.

I wondered if I could, Mr. Chairman, also to follow up. Dr. Solomon, you said that the earth will see essentially a one-half to one degree increase in global temperatures even if CO_2 remains at current levels, and that that temperature increase is irreversible with carbon dioxide levels remaining at their current levels. That was your testimony a minute ago?

CARBON SEQUESTRATION

Now, that is not entirely accurate because it is not, the CO_2 levels are not irreversible. I just, we just established for the record that 90 percent of the carbon dioxide removed from the atmosphere is removed by the ocean, and that you agreed it is proven scientifically, we have got a number of studies that show that you can fertilize the ocean and remove dramatic amounts of carbon dioxide. So we can reverse the levels of carbon dioxide in the atmosphere with ocean fertilization, carbon sequestration techniques that are well established. Woods Hole, the scientist that does this says that if you give him a tanker of iron ore he will give you an Ice Age. And one of the things I really want us to pursue, Mr. Chairman, is to get some research done on this. Because it, I think we should certainly do the research on carbon sequestration since it is possible to remove dramatic amounts of carbon dioxide from the atmosphere by fertilizing the ocean. We want to make sure it is done properly using, and I think you are going to find carbon nanoparticles, nanoparticles of iron oxide as the most effective way to do it. And that NOAA is perfectly suited to do this research. But that before we launch on a program, as the witness has testified, to cut petroleum consumption in the United States by 50 percent by 2030, which Mr. Barton tells me would drive the United States back to the output levels of 1920. And certainly we are going to have new technology. But I think in light of the recession and the economic difficulties we are facing it is not a good idea to pass legislation driving American industrial production back to the levels of 1920 at a time of potentially an economic depression. Before we launch into that, Mr. Chairman, I want us to, if we could, seriously explore carbon sequestration using fertilizing the ocean with nanoparticles of iron oxide before we drive America back to the industrial production levels of 1920.

Mr. MOLLOHAN. Well I——

Mr. CULBERSON. That is where we need to go, right, Dr. Solomon? Forgive me, Mr. Chairman, if I could just get her to comment on that.

Dr. SOLOMON. If I may just clarify. Yes, in the absence of ways to take the carbon out of the atmosphere, in the absence of geoengineering to remove the carbon, the warming is irreversible. But you are right, if you could remove the carbon, that is a different story.

Mr. CULBERSON. Thank you very much. Thank you, Mr. Chairman.

Mr. MOLLOHAN. Well, we are going to leave the remedies, the substantive remedies to the authorizing committees. But what we are doing here today, and what the gentleman is helping doing, is laying a good scientific foundation for our decisions with regard to funding of various programs. And also research into promising technologies and techniques that address the problems. Mr. Fattah?

Mr. FATTAH. Thank you, Mr. Chairman. I am basically done. I do not, I am not taking issue with what was said. I do want to clarify the record, however, because I think the Chairman just asked you what level would we have in terms of a rise if there was a melting in terms of the ice sheet. And when my colleague rephrased it I think he put it in a different context. But the important point is, I think, that the issue needs to be, you know, at the very forefront. And both in terms of how to slow emissions and to slow the issue of the loss of trees, which is also a compounding issue in terms of this problems. But also to think more clearly about what we could do about reengineering, also, and to foresee any problems that may happen as we go about combating this significant challenge.

But I do want to thank the Chairman for the hearing, and thank the witness. Thank you.

U.S. PARTICIPATION IN THE IPCC

Mr. MOLLOHAN. Thank you, Mr. Fattah. The Intergovernmental Panel on Climate Change is by definition an international effort. And this is critically important because all nations, as has been pointed out here today in various questions from various members of the panel, because all nations are being asked to participate in decreasing the emission of greenhouse gases. To what extent is the U.S. climate community providing leadership in the IPCC process? And is this important to the quality and success of the IPCC assessments?

Dr. SOLOMON. The U.S. has been among the key contributors to IPCC from its inception, I think, in 1988. We have made major contributions to all three parts of the panel's work. So science, the impacts and vulnerability, also the mitigation studies. I think it is fair to say that IPCC's success owes a great deal to the research and the researchers in the U.S. And I am very pleased to have been able to be part of that.

INTERNATIONAL COOPERATION ON EXCHANGE OF CLIMATE DATA

Mr. MOLLOHAN. What is the state of international cooperation in the acquisition and provision of climate data?

Dr. SOLOMON. That has actually improved quite a lot in recent years, but there is more to do. Maybe ten years ago or so there were countries that were really keeping their data very close and were not willing to share it with the international organizations that distribute it, or with other countries. But a large number of those have been brought in now. And a lot of that has succeeded because of efforts of scientists who meet with other, with their colleagues in other countries, and discuss the value of the data, the reasons why the data needs to be freed up. And so it has really had a lot of success, I think, in freeing up the data and making it more available. There is more that needs to be done, but a large improvement has happened in about the last five to ten years.

EFFECTS OF IPCC ASSESSMENTS ON CLIMATE RESEARCH

Mr. MOLLOHAN. Having led the production of Volume I of the 2007 IPCC Report, which you did, how does production of these assessments affect climate change research and the climate science community?

Dr. SOLOMON. Well I think the influence on research is very interesting. When we work on these assessments it does, I think, enrich us as researchers. It gives us a broadened view of our science. And I think it is fair to say that very few people finish an experience of working on that kind of thing without feeling that they have learned a tremendous amount that has helped them in their own work. It is also, I think it is fair to say, a way to be ambassadors of science to scientists in other countries and also to the public. It allows us to do some things that really are very unique in the regard of capacity building across the scientific community internationally.

It is also, though, incredibly demanding and it does take a lot of time away from doing one's own research. It is probably right about at the limit of the amount of effort that people can devote to it. It has been very popular so people have asked for more and more products. And while that has been helpful it has gotten to the point where it would be difficult to do more.

I think the other thing that I want to mention is the importance of keeping the research design separate from the assessment. One wants to keep the science independent. And one does not want to have the assessments drive the science too much. And they do not. The way it is currently formulated there is a very careful and strong separation between the doing of research, the funding of research, the type of thing that you do, of course, and the assessment activities. And I think that separation is healthy all the way around. But it is important to know what the users want and that is an aspect of it as well.

Mr. MOLLOHAN. Dr. Solomon, I have a few more questions even in this line of questioning and then some to submit for the record other than that. But we are getting to the witching hour and I want to make sure every member of the panel has two rounds of questioning. And Mr. Schiff has returned so I am going to yield to Mr. Schiff. Mr. Schiff.

LOCAL EFFECTS OF RENEWABLE ENERGY

Mr. SCHIFF. Thank you, Mr. Chairman. I will be very brief. I just have one follow up question on your written testimony. You mentioned that new questions arise regarding some of the alternative sources of energy, such as how a large solar or wind array might modify local climates. I have heard arguments made about this, and I apologize if one of my colleagues has already asked you about this. But I am interested to know, you know, what the state of knowledge is on this. Some of the opponents of renewable energy claim that the wind towers are going to cool, or may raise temperatures by taking the energy from the wind, and the solar arrays may have a reflective impact adverse to global warming. What do we know? And what additional methods of gathering data do we need to get good answers to those questions?

Dr. SOLOMON. Yes, it is a very difficult question because a lot of the effects are extremely local, or associated with the presence of the array in a particular region. So you are really drilling down to a level of understanding of the meteorology that is, at least in the long term, how it is going to change in the long term, is very hard for us to quantify.

Mr. SCHIFF. Is even a large, a very large solar array, I mean, just by way of background, I may have mentioned this at a prior hearing, I was very encouraged visiting an organization called Idealab out in my district that spins off a lot of new high tech companies. They spun off a company called eSolar which will open a solar power plant in a couple of months that will, for the first time, through a combination of technology that tracks the sun's movement and concentrates sunlight on a smaller surface area, produce electricity through solar cheaper than you would through natural gas, which I think is a real milestone. It will be the first basically non-subsidized solar energy. You do not need to subsidize something that is already cheaper than the alternative.

But even with a—and these are scalable—they can be small or you can scale them up large. But even with a large solar array, does it really have a demonstrable impact even on the local climate?

Dr. SOLOMON. It depends on the environment, as far as the local climate goes. I think you are exactly right that on the large scale, you know, the effect on global climate can readily be calculated and it is not big. But when you put something really concentrated in small region it merits a little bit of attention, at least, as to, you know, how big of a local perdivation might this be. And I think we have to look at those kinds of things carefully. Case by case could be certainly quite different. I am afraid I cannot give you a general answer on that.

Mr. SCHIFF. I mean, how would it even, scientifically how would it even work? I mean, how, let us look at a wind farm. What, are you reducing the force of the winds because you are taking the energy from the winds, and therefore downwind you have less energetic winds? And is that the impact you would be looking at?

Dr. SOLOMON. I think one of the main concerns with wind is the fact that it stirs up the nighttime boundary layer. So normally at night the lowest layer of the atmosphere becomes, you know, quite stable. But when you have a lot of these big wind turbines in a concentrated region you can actually stir that up, and really change the local meteorology. So, as I understand it, that is one of the questions to look at. Whether that is a problem or not, you know, lots of places it probably would not be.

With the case of solar, you know, you are absorbing a great deal of energy that would otherwise be hitting the ground in that area. How much of a local change that produces, and whether that is an issue or not is, again, the kind of question that I think people are really trying to ask in a very careful way, project by project. It is only, I think, to say that we cannot afford to ignore side effects, just as I would be concerned about the ability to geoengineer and be sure that everything was fine before we understood everything, I think we also have to at least devote some attention to what the alternatives might do to us.

Mr. SCHIFF. Thank you, Mr. Chairman.

CLOSING STATEMENT

Mr. MOLLOHAN. Thank you, Mr. Schiff. And Dr. Solomon, thank you so much for your testimony here today. We appreciate the benefit of what has been very expert testimony. Your taking time to do that and your contribution to this issue generally are very much appreciated. We look forward to working with you in the coming days and weeks and months on these issues. We will turn to you for advice in the future if that is all right. And most immediately, we will turn to you for comment on some questions that members may want to submit for the record. And I know that I certainly want to. You have laid a great foundation for the hearings to come this week and, again, we are very appreciative of your testimony and your appearance here today. Thank you.

QFR Solomon

The American Recovery and Redevelopment Act of 2009 provides $170 million for climate modeling in NOAA and the supercomputing capability to support it. NSF has under consideration a major expansion of the computing capability of the National Center for Atmospheric Research in part to support enhancements to the community climate model.

1. How would you characterize the current state of climate assessment modeling, and what do you see as key improvements in the next few years?

We have learned a great deal about climate modeling, due to the dedicated efforts of the many modeling groups worldwide who build, and run models. The remarkable group at Lawrence Livermore's Program for Climate Model Diagnosis and Intercomparison (PCMDI) also played a key role by archiving the model data and making it available. This emphasizes that the state of the work is strong due to the way in which the climate models are run, shared, and analyzed in an outstanding example of national and international scientific cooperation and learning due to a generous community spirit. Among ongoing efforts to do even more, many scientists are reaching out across discipline boundaries to do more work linking the physical models to impacts and biological effects in marine and terrestrial ecosystems, and also to better link physical models and strategies for adaptation and mitigation. There is much more to do in these interdisciplinary topics, and it is a key area for improvement.

There were many significant advances in climate change modeling during the years of the Intergovernmental Panel on Climate Change (IPCC) fourth assessment. Much of this can be characterized as moving beyond just global warming to understanding the full climate change system. First and foremost among the breakthroughs was the better understanding of rainfall patterns: this went far beyond previous work and was greatly aided by the availability of not just one or a few models as in the past but by having so many different models: 23 of them worldwide. The exercise showed the special value of the multi-model ensemble and work is continuing to further understand how to compare, for example, the variability statistics in data and models, and to better understand extreme events and to do a better job in simulating them. Key improvements are needed in modeling how climate change affects climatic factors including storm tracks, storm intensity, heat waves, hurricanes, drought, heavy rainfall, etc. There are many areas where we need to build better and more comprehensive models. Improvements in land-surface interactions are needed to improve some of these factors, such as drought. Sea ice treatments also need work – the models underestimated the rate of sea ice loss currently being observed in the Arctic, a serious discrepancy that needs to be understood. Another major issue is feedback between warming and the carbon and nitrogen cycles. As the planet warms, how much carbon comes back from the soil, from trees, and perhaps released not only as CO_2 but also as methane from permafrost is a very serious issue. These uncertain feedbacks could limit the ability to put brakes on the warming in the future even with big reductions in manmade emissions. Understanding of climate change effects on the oceans is also very important, both in terms of ocean circulation changes such as slowing of the 'Gulfstream' and in terms of issues including ocean acidification, and the possible formation of 'dead zones' of reduced oxygen in the ocean. These effects could have very large impacts on marine ecosystems and marine resources. More advanced coupled modeling including the ice sheets and ice flow dynamics is a major issue impeding our ability to confidently project future sea level rise. Improving our ability to model at higher spatial and temporal scales is very important, particularly to inform both mitigation and adaptation decisions.

2. What is the current state of seasonal to interannual climate prediction ability, and has the capability reached the point where operational forecasts should be made?

Seasonal to interannual forecasts are already being made available routinely and are essentially operational.

3. In improving climate modeling, to what extent is progress limited by understanding, by availability of data, and by computing capability?

All three are important. Understanding is fundamental to improving confidence in future projections and in our ability to attribute past changes. Computing capability is key to understanding because it takes a long time to do these runs, because we need to do them at higher spatial scales to get better results, and we need to do them with more sophisticated treatments of some of the terms such as the carbon cycle or atmospheric chemistry, all of which place very large demands on computing resources. Availability of data is not a major obstacle to progress at the moment but this is only because of the extraordinary efforts of people who have been making the model data available. Availability of data would be a problem in the future unless there is a large effort directed at ensuring continuing improvements, since there will be a lot more data as models are run at increasingly higher resolution.

Numerical modeling of the atmosphere preceded comparable modeling of the oceans with their greater complexity and observational challenges.

4. To what extent do inadequacies in current modeling and observation of the oceans on local, basin and global scales contribute to uncertainties in climate change predictions and assessments?

There are many challenges in modeling the oceans, and the oceans are very important for reducing uncertainty in climate change predictions and projections. At the global scale, understanding how the thermohaline circulation is changing and will change in the future is critical, and our models are limited there in part because of the uncertainties in ice sheet modeling: the freshwater discharge from the ice sheets may be very important but modeling is very limited. We need to understand ocean transports better to understand ocean acidification and how it may affect corals and fish, but models and observations of this are currently very limited. We also have limited data coverage of ocean heat uptake, particularly the deep ocean, and this is critical because it is where most of the heat added to the system goes, and it is essential for sea level rise. It is also important for a better understanding of the sensitivity of climate to increases in greenhouse gases or aerosols. More observations are needed, and we need to ensure a full understanding of the differences between new and old ocean data systems. We have a strong need to better understand how the various ocean basin changes link to atmospheric changes, for example, how global warming may influence the frequency or intensity of future North Atlantic Oscillation events, how global warming will influence Indian ocean warming and how these all of these modes of ocean variability may change and thereby affect rainfall patterns worldwide.

Clouds pay a major role in the transfer of radiation through the atmosphere, both incoming sunlight and outgoing infrared radiation from Earth's surface. The contribution of clouds to climate change depends on the altitude at which increased cloud cover may occur, and phenomena inside clouds are challenging to model and measure.

5. To what extent do inadequacies in current modeling and measurement of clouds and their effects on radiation transfer, heat transfer, and precipitation contribute to uncertainties in climate change predictions and assessments?

Clouds have been a major uncertainty in climate change projections for decades. Much is being learned now due to new cloud satellite information (e.g., CALIPSO and CLOUDSAT), so there is a great deal of progress occurring but more is badly needed. In terms of modeling of these effects, higher resolution is likely to help, because a key problem is parameterizing the clouds using grids that are too large. Reanalysis of past data to improve consistency over the available record is also needed. Rainfall is highly uncertain in many places, although the uncertainties are larger in some places than others – in the subtropics we know more than we do in midlatitudes. Uncertainties in observing and modeling clouds are a key driver of the inability to confidently project rainfall changes in many regions, including for example, the US Midwest. A major issue is the extent to which manmade aerosol particles influence clouds and rainfall. This is very poorly understood and may be extremely important.

6. Looking forward, what do you think is the appropriate and ideal way for the U.S. Government, both Congress and the executive branch, to stay abreast of developments in climate science so that they can be factored into policy, legislation, and budgets?

Deliberative assessment processes are a proven way for the U. S. Government to stay abreast of developments in challenging environmental science issues as one key input to policy, legislation, and budgets. This includes IPCC, as well as reports prepared under the auspices of the U. S. National Academy of Sciences including the current America's Climate Choices report, and other assessments such as those of the Climate Change Science Program. Such assessments are particularly valuable because they provide the shared views of numerous scientists following a joint process to identify robust conclusions and significant uncertainties. They are rigorously reviewed, and are subject to well-defined oversight procedures. Assessments carried out on the topics of, for example, ozone depletion and acid rain, played key roles in providing balanced information that proved useful to the U. S. in its leading policy role in the Montreal Protocol on safeguarding the ozone layer, and in legislation and bi-lateral agreements on acid rain. Such assessed information has also proven particularly useful for budget planning since it allows an open evaluation of key uncertainties and related research needs.

In the past 5-years, we have seen a dramatic decrease in the amount of Arctic summer sea ice. There is a published study that relates the summer open Arctic Ocean to the drought in the southwest United States.

7. Do you expect the trend in arctic sea ice to continue, and can we expect this decrease to alter the climate in other regions of the northern hemisphere?

It is very likely that trends in Arctic sea ice will continue, although it is not clear whether the next few years will continue to show very large losses as in 2007 and 2008, or whether the sea ice trend will go back to the type of behavior seen prior to 2007. There is significant scientific debate on the question of the likely future Arctic sea ice changes, with some scientists arguing that the unusual and unexpected loss of thicker multi-year ice that occurred in 2007 has shifted the Arctic to a new state, while others suggest that the presence or absence of multi-year may be less important than other factors such as how much snow falls on the ice and insulates it against summer season retreat. There are a few studies beginning to suggest that the changes in Arctic sea ice are sufficient to alter storm tracks and rainfall patterns outside the polar regions. This is not unexpected, since the ice is very important in thermal and hydrologic budgets. One study suggested that sea ice retreat might cause drought in the northwestern US, while another emphasized increased precipitation over parts of Europe. More studies with several different models are needed to ensure we understand these potentially important effects.

QUESTIONS FOR THE RECORD, from Mr. Aderholt, Hearing date: March 17, 10:00a.m.

Hearing: Status of Climate Change Science

Witness: Dr. Susan Solomon

Question 1: Climate models form the basis for projections of human-caused warming in the next century. Some scientists have attempted to use these models to reproduce the past. In looking at the past 30 years (1979 – 2008), over which we've had true global temperature coverage, IPCC model projections predicted a temperature increase of over 0.20 °C per decade, while the actual trend was only 2/3 of this – and the results are even worse when only considering the past 15 years. I am trying to understand how well our climate models represent the actual climate system. I am told that we have global temperature records for the past 30 years. If we were to start the models with the global conditions as they existed 30 years ago, how would the model projections for today compare with the climate that we actually observe today?

This question is addressed in detail in chapters 1 and 9 of the IPCC climate change science report (2007). Chapter 1 showed the level of agreement between numerical projections of climate change and observations since IPCC assessments began in 1990. As can be seen in the graph, the actual warming trend has been about 0.1°C per decade (Figure 1.1 appended below). The figure also shows that the IPCC projections agree with this value within error estimates. Earlier analyses of global average surface temperatures extend back to the 19th century, more than 100 years. These rely on station observations and are extensive enough to document the global average trends, as shown in many published papers. They are also in agreement with satellite observations since 1979 within respective error bars, as detailed in chapter 3 of the IPCC (2007) report. Chapter 9 of the IPCC (2007) report showed how the models compare to those observations in detail. Ten year averages are used here to ensure careful distinction between interannual variability and long-term climate change (i.e., the distinctions between weather and climate). As can be seen in the attached figure from chapter 9 of the report, the agreement between models and observations of warming over the period of the past 30 years or over the full period of the 20th century is quite good when manmade greenhouse gases are considered, but does not reproduce the measurements when only natural forcings are considered. The figure also shows an important fingerprint of climate change, that land areas are warming more than oceans in the global average, as predicted by the models.

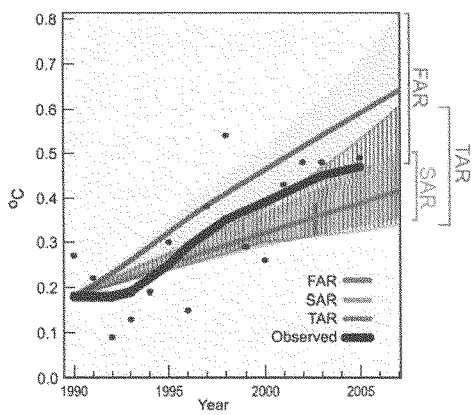
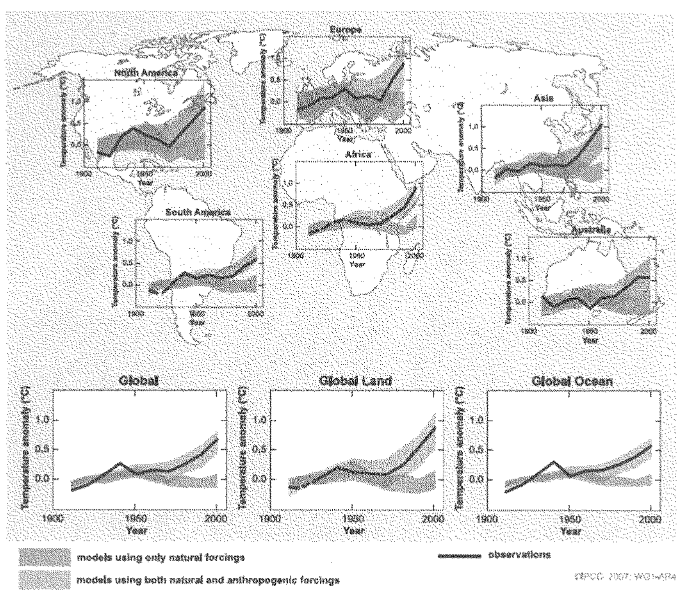


Figure 1.1. *Yearly global average surface temperature (Brohan et al., 2006), relative to the mean 1961 to 1990 values, and as projected in the FAR (IPCC, 1990), SAR (IPCC, 1996) and TAR (IPCC, 2001a). The 'best estimate' model projections from the FAR and SAR are in solid lines with their range of estimated projections shown by the shaded areas. The TAR did not have 'best estimate' model projections but rather a range of projections. Annual mean observations (Section 3.2) are depicted by black circles and the thick black line shows decadal variations obtained by smoothing the time series using a 13-point filter.*



FAQ 9.2, Figure 1. *Temperature changes relative to the corresponding average for 1901-1950 (°C) from decade to decade from 1906 to 2005 over the Earth's continents, as well as the entire globe, global land area and the global ocean (lower graphs). The black line indicates observed temperature change, while the coloured bands show the combined range covered by 90% of recent model simulations. Red indicates simulations that include natural and human factors, while blue indicates simulations that include only natural factors. Dashed black lines indicate decades and continental regions for which there are substantially fewer observations. Detailed descriptions of this figure and the methodology used in its production are given in the Supplementary Material, Appendix 9.C.*

Question 2: Congress is currently considering a number of policy options for limiting carbon dioxide emissions, many of which could result in increased energy costs. Therefore, it is important that the impact of these policy options be well-understood. Today, policymakers are relying on climate models to predict the effectiveness of the policy options in terms of the actual impact of the policy on our climate, and therefore it is critical that the climate models themselves be robustly tested. Yet, today, it seems that the validity of climate models is tested and reported by the model creators themselves. Given the large economic impact of the legislative proposals being considered by Congress as a means to reduce carbon dioxide emissions, it seems that we need to ensure that the climate models that are used to assess the effectiveness of these legislative proposals must be robustly tested. Would you be opposed to the establishment of independent "red teams", comprised of scientists who are not funded to build and run climate models, as a way to test the validity and robustness of the various climate models?

Many different research groups and institutions already are heavily involved in testing, analyzing, and documenting through peer reviewed publications a wealth of information on climate models and their comparison to observations. There are many such activities underway already in institutions that are not those that created the models. This is made possible because the results are already made publicly available for analysis by any expert. Competition between research groups to provide such analysis is very important, and it would not be appropriate to establish a particular closed set of 'red teams'. Since anyone can obtain and analyze the information, an open process now exists, which also ensures that the funding to do such work, and the resulting outputs, are subject to appropriate peer review. This is the best approach to ensuring competition and quality in my opinion.

Question 3: The climate is very sensitive to cloud coverage, which shades the Earth from sunlight. Yet, clouds are one of the least understood components of climate models. How well understood is the role of clouds in climate model projections, and is this a technical area that needs to be better investigated?

Clouds have been a major uncertainty in climate change projections for decades. Much is being learned now due to new cloud satellite information (e.g., CALIPSO and CLOUDSAT), so there is a great deal of progress occurring but more is badly needed. In terms of modeling of these effects, higher resolution is likely to help, because a key problem is parameterizing the clouds using grids that are too large. Reanalysis of past data to improve consistency over the available record is also needed. Rainfall is highly uncertain in many places, although the uncertainties are larger in some places than others – in the subtropics we know more than we do in mid-latitudes. Uncertainties in observing and modeling clouds are a key driver of the inability to confidently project rainfall changes in many regions, including for example, the US Midwest. A major issue is the extent to which manmade aerosol particles influence clouds and rainfall. This is very poorly understood and may be extremely important.

WEDNESDAY, MARCH 18, 2009.

CRITICAL SATELLITE CLIMATE CHANGE DATASETS

WITNESSES

DR. ANTONIO BUSALACCHI, PH.D, UNIVERSITY OF MARYLAND
DR. TOM KARL, PHD, NOAA CLIMATE DATA CENTER

OPENING STATEMENT BY CHAIRMAN MOLLOHAN

Mr. MOLLOHAN. The hearing will come to order. Our Ranking Minority Member Mr. Wolf will be along shortly, but he has asked that we proceed. So good afternoon, Dr. Busalacchi.

Mr. MOLLOHAN. And Dr. Karl. I have a son named Carl. Welcome before the Committee on Commerce, Justice, Science and Related Agencies. We appreciate your coming today to help us understand the requirements for long term satellite observations to support the understanding, prediction, and monitoring of climate change and the specific characteristics required of the systems that provide them.

Requirements for precision, accuracy, calibration, and continuity influence cost, but meeting these requirements is critical to getting value from investments in Earth observations. For example, the just enacted Omnibus Appropriation for Fiscal Year 2009 provides $74 million to restore two climate instruments to the payload of the NPOESS satellite, and $150 million to accelerate development of Earth observation satellites recommended by the National Research Council. In addition, the resulting data must be preserved; it must be managed, and made available for analysis.

We have asked each of you to focus on the critical insight into climate change contributed by particular sets of satellite observations, together with ground-based, ship, aircraft, balloon, and buoy instruments.

Dr. Busalacchi, we have asked you to cover oceans data, an example of which is displayed on the wall behind me. Satellite remote sensing has proven quite helpful in oceanography even though the penetration of electromagnetic radiation into ocean water is limited. Dr. Karl, you have dedicated many years to leading the National Climate Data Center with its treasure of atmospheric data. We have asked you to cover atmospheric observations and the role and requirements of climate data systems.

Your written statements will be made a part of the record. And let me welcome you, thank you for taking time, traveling distances, to be with us today. We very much appreciate the opportunity to have the benefit of your expertise. We will be referring to it as we process this appropriation bill. And we look forward to your testimony. As I mentioned, your written statements will be made a part of the record and Dr. Busalacchi, why do you not proceed?

Dr. BUSALACCHI. Thank you, Chairman Mollohan.

Mr. MOLLOHAN. Because if I wait for you to be second I might forget how to pronounce it.

OPENING STATEMENT

Dr. BUSALACCHI. Very good. Thank you, Chairman Mollohan, members of the Committee. Thanks for this opportunity to testify before you this afternoon. I am Dr. Tony Busalacchi, Director of the Earth System Science Interdisciplinary Center and Professor of Atmospheric and Oceanic Science at the University of Maryland. I also—go Terps! I also serve as Chair of the Joint Scientific Committee for the World Climate Research Program. And I will use my time today to summarize the key role of oceanographic satellite observations in advancing climate understanding and prediction.

Satellite measurements have revolutionized our understanding of ocean circulation, marine biology, and interactions with the atmosphere. I am often asked the question, "If we cannot predict our weather more than a week in advance, why should one believe we can predict future climate?" The answer to that question rests within the ocean, for it is the thermal inertia of the ocean, that is the longer time scale at which heat moves within the ocean relative to the atmosphere, that enables climate forecast from seasons out to a year in advance with the realistic prospect of extension to years and decades. On longer decadal to centennial time scales it is climate change that brings new risks to marine life due to ocean warming, changes in circulation, sea level rise, and acidification from increased atmospheric carbon. Yet, many of the measurements needed to monitor and predict such changes are now at risk because of budget constraints and the lack of a national strategy to sustain them.

Of all the ocean climate variables, sea surface temperature is the most important as it is the one variable that couples the ocean surface to the atmosphere. Going back to the late 1970's, sea surface temperature has been provided by orbiting infrared radiometers and complemented more recently by microwave passive radiometers. Ocean surface temperature is one of the most important indicators of global climate change and is used in a wide range of ocean climate studies, from that of the Gulf Stream in the Atlantic to El Niño in the Pacific Ocean. This climate data record, spanning thirty years, has been calibrated, validated, reprocessed with surface observations from ships, buoys, and drifters.

In contrast to the meteorological observations used to initialize a weather forecast, the construction of such climate data records has unique requirements for instrument characterization, calibration, stability, continuity, and data systems to support climate applications. Space based climate observations are not a mere extension of those used to monitor and forecast the weather.

Since 1992 high precision radar altimeters, beginning with the U.S./France TOPEX/Poseidon mission, have been monitoring changes in sea level. Sea surface topography is not only a proxy for the amount of heat stored in the ocean, but much akin to the highs and lows on a weather map, provides valuable information regarding the global ocean circulation. Monitoring the heat stored in ocean eddies is also providing new insights as to how heat content can lead to hurricane intensification, as was the case with Hurricane Katrina. Unfortunately at the present time the U.S. has not yet secured the next series of the follow on radar altimeters known as Jason 3.

A different sort of radar instrument, the scatterometer, provides crucial information regarding ocean surface wind speed and direction that forces worldwide ocean currents. By measuring how a radar signal is backscattered off the sea surface of the ocean, a synoptic view is provided of the surface wind velocity. These data have yielded new insights into the exchange of heat and momentum between the atmosphere and the ocean.

Important information on ocean biology is obtained from the color of the ocean, as you see right behind you. This estimate of marine biomass can be related to how and where the marine ecosystem takes up and sequesters carbon. The first worldwide continuous monitoring of ocean color did not begin until 1997 with the launch of the SeaWiFS mission. In fact, that picture was produced by my lab at Goddard when I was the lab chief for that project. This class of global ocean color observations has continued to the present day with the MODIS sensor on the NASA Aqua satellite. Yet once again, unfortunately the continuation of such a data record is in serious jeopardy due to degraded performance specifications with the VIIRS sensor scheduled for the forthcoming NPOESS Preparatory Project.

While great strides have been made in satellite oceanographic research we face some fundamental challenges in making the transition from research to sustained operations. Last year I chaired the National Academy's "Panel on Options to Ensure the Climate Record for the NPOESS and GOES—R Spacecraft." This study was in response to a NASA and NOAA request for a follow on report to the decadal survey in Earth science that focused on the recovery of lost climate measurement capabilities resulting from the Nunn-McCurdy process. In the decadal survey it was noted there is a lack of clear agency responsibility for sustained research programs, and the transitioning of proof of concept measurements into sustained measurement systems. In our NPOESS study we recommended that our nation needs a deliberate, forward looking, and cost effective strategy for satellite based environmental monitoring. In conclusion, the nation requires a coherent strategy for Earth observations which provides for an operational climate monitoring and prediction, scientific advances, and the continuation of long-term measurements. The nation deserves such a strategy.

Thank you for the opportunity to appear before you today on this important topic. And I am prepared to answer any questions you may have. Thank you.

[Written statement by Antonio J. Busalacchi, Jr. Ph.D., Chairman, Joint Scientific Committee, World Climate Research Programme follows:]

THE ROLE OF SPACE-BASED OCEAN OBSERVATIONS IN SUPPORT OF CLIMATE UNDERSTANDING AND PREDICTION

Statement of

Antonio J. Busalacchi, Jr., Ph.D.
Chairman, Joint Scientific Committee, World Climate Research Programme
and
Director, Earth System Science Interdisciplinary Center (ESSIC)
University of Maryland

before the

Commerce, Justice, Science, and Related Agencies
Appropriations Subcommittee
U.S. House of Representatives

March 18, 2009

Good afternoon. Chairman Mollohan and members of the committee, thank you for this opportunity to testify. I am Dr. Tony Busalacchi, Director of the Earth System Science Interdisciplinary Center and Professor of Atmospheric and Oceanic Science at the University of Maryland. I also serve as the Chair of the Joint Scientific Committee for the World Climate Research Programme. I will use my time this afternoon to summarize the key role of oceanographic satellite observations in advancing climate understanding and prediction.

Satellite measurements have revolutionized our understanding of ocean circulation, marine biology, and interactions with the atmosphere. I am often asked the question, "If we can't predict our weather more than a week in advance, why should one believe we can predict future climate?" The answer to that question rests within the ocean. For the case of day to day weather prediction, comprehensive observations of the atmosphere are fed into complex numerical models. This initial state of the atmosphere is then integrated forward in time based on the governing equations of motion for the atmosphere alone. After several days, errors in these initial conditions and nonlinearities in the system begin to take over and the prediction skill falls off dramatically after one week. However when this same type of numerical weather prediction model is coupled to an interactive ocean, only then can the forecast lead time be extended. For it is the thermal inertia of the ocean, i.e., the longer time scale at which heat moves within the ocean relative to the atmosphere, that enables climate forecasts from seasons out to a year in advance with the realistic prospect of extension to years and decades. On longer decadal to centennial time scales, it is climate change that brings new risks to marine life due to ocean warming, changes in circulation, sea level rise, and acidification from increased atmospheric carbon. Yet, many of the measurements needed to monitor and predict such changes are now at risk because of budget constraints and the lack of a national strategy to sustain them.

The ocean climate community has three basic observational needs: (1) sustained, continuous, and often overlapping, measurements of certain key oceanographic parameters critical to monitor long-term climate trends and to validate coupled ocean-atmosphere climate models, (2) observations to initialize and force coupled climate prediction models, and (3) new or improved measurements of additional key parameters to advance ocean climate science and reduce uncertainty in our understanding of climate processes and interactions within the coupled ocean-atmosphere system. Due to the remoteness of the vast oceans, satellites have provided the foundation for the first truly global ocean observing system. Prior to the satellite era, ocean observing platforms included ships, fixed moorings, drifting buoys, and island stations, none of which, even when taken together, could provide basin-scale coverage at the spatial and temporal scales required to resolve the dynamic nature of the ocean. Satellite data from infrared radiometers, scatterometers, altimeters, and ocean color sensors have opened up a new field of satellite oceanography and, as a result, yielded new understanding of how mass is transported within the ocean, how energy is exchanged with the atmosphere, and the role of the ocean in the global carbon cycle.

Of all the ocean climate variables, sea surface temperature is the most important as it is the one variable that couples the ocean to the atmosphere. Observations of sea surface temperature have the longest heritage in ocean remote sensing. Going back to the late 1970's, sea surface temperature has been provided by orbiting infrared radiometers and complemented more recently by all-weather passive microwave radiometers. Ocean surface temperature is one of the most important indicators of global climate change and is used in a broad range of ocean climate studies such as changes to the Gulf Stream circulation and the El Nino/Southern Oscillation. The climate data record provided by the order 30 years of sea surface temperature observations has been calibrated, validated, and reprocessed with surface observations from ships, buoys, and drifters. In contrast to the meteorological observations used to initialize a weather forecast, the construction of such climate data records has unique requirements for instrument characterization, calibration, stability, continuity, and data systems to support climate applications. Space-based climate observations are not a mere extension of those used to monitor and forecast the weather.

Understanding increases in sea surface temperature and anthropogenic heat input to the surface ocean have important ramifications for quantifying and predicting sea-level rise. Since 1992 high-precision radar altimeters, beginning with the joint U.S./France TOPEX/Poseidon mission, have been monitoring changes in the ocean surface topography. Sea level is not only a proxy for the amount of heat stored in the ocean, but much akin to the highs and lows on a weather map, fluctuations in the sea surface topography provide valuable information regarding the global ocean circulation. Monitoring the heat stored in ocean eddies is also providing new insights as to how upper-ocean heat content can lead to hurricane intensification as was the case with Hurricane Katrina. Even after 17 years of observations, I find the radar altimeter to be a marvelous feat of technology. Similar to the radar gun in a police car, a satellite altimeter sends down radar pulses from 1300 km in orbit and senses changes in sea level to within 2 centimeters. That is like standing here in Washington and monitoring changes in the elevation of the St. Johns River in Jacksonville, Florida to within one inch. Unfortunately, at the present time the US has not yet secured the next in the series of follow-on radar altimeters, known as Jason 3, required to continue this valuable record.

A different sort of radar instrument, the scatterometer, provides crucial information regarding the ocean surface wind speed and direction that forces world-wide surface currents. By measuring how a radar signal is backscattered off ever increasing wind-driven ripples on the sea surface, a synoptic view is provided of the surface wind velocity. These data have yielded new insights into the exchange of heat and momentum between the atmosphere and ocean. Weather forecasting has also been significantly improved by incorporating scatterometer-derived winds into forecasts. For example, scatterometer data are particularly useful for determining the location, strength, and movement of cyclones over the ocean.

Most of the space-based ocean observations I have described to this point are specific to the physics of the ocean. Important information on ocean biology is obtained from the color of the ocean. The ability to derive global maps of chlorophyll concentration in the upper ocean from ocean color sensors was a remarkable achievement for the oceanographic community. This estimate of marine biomass can be related to how and where the marine ecosystem takes up and sequesters carbon. The first ocean color sensor was the Coastal Zone Color Scanner (CZCS), an experimental proof of concept mission operating on the Nimbus 7 satellite between 1978 and 1986. The CZCS demonstrated that it is possible to detect subtle changes in the color of the ocean and relate these to the concentration of chlorophyll from marine phytoplankton in the upper ocean. The first truly world-wide continuous monitoring of ocean color did not begin until 1997 with the launch of the SeaWiFS mission. This class of global ocean color observations has continued to the present day with the MODIS sensor on the NASA Terra and Aqua satellites. Such satellite observations provide the only means of estimating and monitoring the role of ocean biomass as a sink for carbon. Yet, once again, unfortunately, the continuation of the quality of such a data record is in serious jeopardy due to degraded performance specifications with the VIIRS sensor scheduled for the forthcoming NPOESS Preparatory Project.

While great strides have been made in satellite oceanographic research, we face some fundamental challenges in making the transition from research to sustained operations. Last year I chaired The National Academies' "Panel on Options to Ensure the Climate Record from the NPOESS and GOES-R Spacecraft." This study was in response to a NASA and NOAA request to the National Research Council for a follow-on report to the Decadal Survey in Earth Science that focused on recovery of lost measurement capabilities, especially those related to climate research, which occurred as a result of changes to the NPOESS and GOES-R satellite programs. In the Decadal Survey it was noted there is a lack of clear agency responsibility for sustained research programs and the transitioning of proof-of-concept measurements into sustained measurement systems. Sustained climate observations require a long-term strategy. Much of the climate science as I have outlined here today depends on long-term, sustained measurement records. Yet, as has been noted in many previous NRC and agency reports, the nation lacks a clear policy to address these known national and international needs. Institutions have responsibilities that are in many cases mismatched with their authorities and resources: institutional mandates are inconsistent with agency charters, budgets are not well matched to emerging needs, and shared responsibilities are supported inconsistently by mechanisms for cooperation. While my comments today have been based on satellite oceanography, in our NPOESS study we recommended that, in a broader context, our nation needs a deliberate, forward looking, and cost-effective strategy for satellite-based environmental monitoring. The nation requires a coherent strategy for Earth observations which provides for operational climate monitoring and prediction, scientific advances, *and* the continuation of long-term measurements. The nation *deserves* such a strategy. Thank you for the opportunity to appear before you today on this important topic. I am prepared to answer any questions you may have.

Mr. MOLLOHAN. Thank you, Dr. Busalacchi. Dr. Karl.

OPENING STATEMENT

Dr. KARL. Thank you, Chairman Mollohan, and good afternoon other members of the Subcommittee. My name is Tom Karl. I am the Director of NOAA's National Climatic Data Center. And I have also been asked to lead NOAA's Climate Services.

First off, I just want to express to you how honored I am for asking me to really talk about the role satellites can play in the climate change arena, in particular climate data records. This is extremely important for us. I emphasize the word can, because satellites can play an extremely role but it is rare that satellite data that is rapidly produced for weather products and derived from satellite sensors directly are rarely useful for climate change issues. Rather, what is required is an ordered series of sophisticated technical processes developed through decades of scientific achievement. That is what is needed to convert the raw satellite sensor records that we receive into something we call climate data records. I will be using that term frequently, so if you do not mind if I just call it CDRs that is what I will mean by shorthand for climate data records.

As defined by the National Research Council a CDR, or climate data record, is simply a timed series of measurements of sufficient length, consistency, and continuity to determine climate variability and change. In practice, CDRs or climate data record development requires careful integration of archived data from many different satellites and sensor designs. And this is supplemented with non-satellite observing system data, as Chairman Mollohan indicated during his introductory remarks.

Most experts agree that a climate data record, CDR, must extend over multiple decades to unambiguously discern changes in climate. With shorter periods climate signals or effects can be misinterpreted or altogether masked due to normal environmental variability, changes in instrument characteristics, changes in the behavior of the instrument over time, changes in satellite orbits. One thing is clear, CDR development cannot be constrained to single satellite missions.

But CDRs indeed are required for studying climate change. In its fourth assessment report in 2007 the IPCC, the Intergovernmental Panel on Climate Change, stated in its consensus opinion on the state and likely future changes of the Earth's climate that there were a number of confident conclusions that could be made in that report, but there were also notable exceptions. And those were often linked to the quality of the data from which the IPCC had to work with. So clearly limitations in datasets are extremely important in terms of our understanding of climate change.

The real challenge in developing climate data records suggests that now we do have significant information latent in our data archives. There is a number of recent CDR successes, Dr. Busalacchi mentioned a few of them, related to important issues. And I can just name a few that, I got into more detail in my written testimony. Changes in important aspects of the climate, like hurricane intensity. If you remember a few years ago there was a major controversy between the differences in the rates of warming at the surface, and that in the upper levels of the atmosphere as measured by satellite and measured by surface measured changes. Changes in vegetation have been well demonstrated to be extremely important in terms of using satellite data and climate data records.

So based on these studies, the World Meteorological Organization, National Research Council, the Climate Change Science Program, the Global Climate Observing System, numerous other authorities, have increasingly called for a comprehensive CDR program derived from a set of forty-four essential climate variables. And today there really is some great urgency to begin this work before the launch of NPP and NPOESS, particularly in light of the massive amount of data that these two systems will be generating in the near future.

So thanks to about fifty years of satellite weather observations and more than thirty-five years of computer compatible archived data, we can now construct a comprehensive set of global CDRs. NOAA has archived data from forty-one polar orbiting satellites and fifteen geostationary satellites. NASA and other national and international agencies have complemented these data with more than fifty other Earth observing satellites. NPOESS and NPP promise to sustain even more detailed and comprehensive observations in coming decades. Since most satellites carry multiple remote sensing instruments, the grand challenge in CDR development is to scientifically stitch together all these data from different sensors and different satellites.

This morning I am pleased that I will be able to describe NOAA's new CDR initiative, developed in coordination with NASA. Over the past two years NOAA and NASA have worked on a coordinated interagency solution to develop and sustain climate data records. Thanks to the efforts of this Congress and the continued support of satellite sensors and CDRs in the 2009 American Recovery and Reinvestment Act, NOAA will begin to implement its part of the program. This will include harvesting mature research technologies and applying them to decades of archived satellite data. Further, NOAA will continuously extend the resulting CDRs using current and future satellite observations, including those from NPOESS and NPP.

Given the unique knowledge and extensive experience required to develop world class CDRs, NOAA will largely execute its program through competitively selected experts in academia, industry, nonprofits, NOAA cooperative institutes, and other federal agencies. We will work to ensure that the community knowledge gained through state of the science research programs, such as NASA's Earth Observing System, is captured and incorporated into NOAA operations. NOAA will complement these developments by upgrading its world class data archive and access systems.

Indeed, keeping up with the sheer volume of the data from existing and planned satellites is critical for NOAA's scientific data stewardship. NOAA is currently operating and continuing to develop its comprehensive large array data stewardship system, otherwise known as CLASS. This will provide the information technology necessary to support the CDR program among other programs, and programs like the Climate Data Modernization Program continue to make older previously inaccessible data available for analysis.

So in conclusion there is no question that significant climate change information is currently embedded in the world's archived satellite datasets. NOAA and its partners are now embarking on a comprehensive, systematic, and sustained CDR effort to really help unleash the potential of these data from the past, present, and next generation of operational satellites to inform the nation about ongoing and future climate change. Thanks.

[The information follows:]

WRITTEN TESTIMONY OF
THOMAS R. KARL, L.H.D.
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

HEARING ON
SATELLITES AND CLIMATE
BEFORE THE
COMMITTEE ON APPROPRIATIONS
SUBCOMMITTEE ON COMMERCE, JUSTICE, SCIENCE,
AND RELATED AGENCIES
U.S. HOUSE OF REPRESENTATIVES

March 18, 2009

Introduction

Good day, Chairman Mollohan, Ranking Member Wolf, and other Members of the Committee. I am Thomas R. Karl, Director of the National Oceanic and Atmospheric Administration's (NOAA's) National Climatic Data Center and the Lead for developing and executing NOAA's climate services. I thank you for the opportunity to testify about the unique and critical role satellites play in monitoring climate change. Our ability to monitor changes in climate is fundamental to understanding past, present, and future global climate change across the Nation and the world.

The well-established interconnectivity of the Earth's terrestrial, atmospheric, and oceanic systems requires a comprehensive and global perspective in climate monitoring. Satellites play a central and irreplaceable role in our Earth observing infrastructure, and they provide information that is fundamental to successfully understanding and anticipating climate change.

It is important to note raw satellite data and rapidly produced weather products derived from satellite sensors are rarely useful for climate change studies. Rather, an ordered series of sophisticated technical processes, developed through decades of scientific achievement, are required to convert raw satellite sensor data into Climate Data Records (CDRs). As defined by the National Research Council, a CDR is a time series of measurements of sufficient length, consistency, and continuity that can be used to assess current and foresee future climate variability and change. In practice, CDR development usually requires careful integration of archived data from many different satellites and sensor designs along with data from non-satellite observing systems. Climate scientists have generally had to acquire and process archived data of varying formats, granularity, accuracy and accessibility. As a result, these scientists have typically had to apply extraordinary effort over multiple years to derive CDRs of sufficient length and quality to address a variety of questions and issues related to climate change.

This morning, I will describe NOAA's new initiative – developed in coordination with NASA and in response to calls from the National Academy of Sciences and other expert bodies – to systematically and comprehensively develop and maintain authoritative CDRs. This initiative will lead to accurate long-term products and reduce the amount of time and effort put in to data reanalysis. As a result, our Nation's climate scientists and other professionals will routinely be able to focus on climate change analyses, hypothesis testing, climate change modeling, and climate change adaptation and mitigation studies using CDRs of known quality. The initiative includes state-of-the-art data stewardship and dissemination through NOAA's National Data Centers, and will help ensure CDRs are readily available to the public, easy to understand, and of the highest quality possible. This initiative will result in an acceleration of climate change understanding applicable to mitigation, adaptation, and risk assessment.

Climate Data Records Are Required for Climate Change

In its Fourth Assessment Report of 2007, the Intergovernmental Panel on Climate Change (IPCC) stated its consensus opinion on the state of and likely future changes of the Earth's climate. Although some points were expressed with notable confidence, others were carefully qualified due to the persistent uncertainties in the measurement and simulation of the large and complex Earth system. Indeed, the IPCC also listed key uncertainties and gaps in knowledge and research needs that must be addressed to significantly advance confidence in climate change prediction and understanding. For example, the IPCC found that:

1) Incomplete global data sets for extremes analysis and model uncertainties restrict the regions and types of extremes detection studies that can be performed;

2) The availability of observational data restricts the types of extremes that can be analyzed;

3) Multi-decadal changes in daily temperature range are not well understood, in part because of limited observations of changes in cloudiness and aerosols; and

4) Confidence in attributing some climate change phenomena to anthropogenic influences is currently limited by uncertainties in radiative forcing, as well as uncertainties in feedbacks and observations.

Most of the key gaps and uncertainties about climate, as identified by the IPCC, are directly or indirectly related to the availability of adequate observations and of CDRs when observations exist. This is because, without CDRs, we cannot effectively test our understanding of the climate system. For example, by comparing CDRs with climate model simulations researchers can evaluate and test climate model accuracy, as well as identify causes of particular elements of climate change. Because the ability to provide reliable scenarios of future climate is dependent upon CDRs, it is therefore unavoidably tied to the quality of available observational data sets.

The Challenge of Developing Climate Data Records

Most experts agree that a CDR must extend over multiple decades to unambiguously discern changes in climate. Within shorter time periods, climate signals or effects can be misinterpreted or altogether masked due to normal environmental variability, changes in instrument characteristics or behavior, changes in satellite orbits, and the lack of information about operating conditions in the environment around the satellite sensors. Due to the volume of observations required, CDR development cannot be constrained to a single satellite mission. Thanks to nearly 50 years of satellite weather observations and more than 35 years of operational satellite data in NOAA's computer archives, NOAA can now construct a comprehensive set of global CDRs. NOAA (and its predecessor agency, the Environmental Science Services Administration) has archived data from 41 polar orbiting and 15 geostationary satellites. NASA, currently with 15 on-orbit research satellites, and other national and international agencies have complemented NOAA's operational satellites with more than 50 other Earth-observing satellites. The National Polar Orbiting Environmental Satellite System (NPOESS) and the NPOESS Preparatory Project (NPP) satellite, which will be launched before the series of NPOESS satellites, will sustain even more detailed and comprehensive observations in coming decades. Each satellite carries multiple remote sensing instruments. The grand challenge in CDR development is to scientifically stitch together these data.

Much of the data derived from these satellites have been used successfully for rapid weather forecast and hazard assessment – helping to save countless lives and investments. However, without significant additional research, analysis, and data archive investments, these data are, without question, unsuitable for addressing contemporary climate change questions from IPCC and others. In fact, there is now ample evidence that significant climate change information lies latent in these archives. For example, in the mid-1990s NOAA and NASA worked cooperatively to develop a pathfinder satellite-derived data set that was then used by a Boston University-led team[1] which worked exhaustively to develop a CDR that corrected for biases and instrument inter-calibration related to vegetation growth. These data were derived from a number of NOAA's polar orbiting satellites. After nearly four years of effort, the study revealed an unmistakable correlation between increased vegetation growth in the northern hemisphere and longer growing seasons associated with climate change. These findings also helped to independently confirm observations from other observing systems, including surface-based systems. Similarly, researchers at NOAA's National Climatic Data Center spent four years carefully merging and inter-calibrating a patchwork of data from 29 geostationary satellites – both U.S. and foreign – to develop a CDR to facilitate efficient global analysis of hurricanes. Within a year of completing the CDR, a team of scientists from Florida State University and University of Wisconsin used the resulting data set to objectively determine increases in hurricane intensity in the major ocean basins around the world since the early 1980s[2]. More often than not, however, a single team of scientists using a specific observing system to develop a CDR cannot effectively resolve climate change signals. CDRs that are not developed using multiple approaches and multiple satellite and Earth-based observing systems are often problematic. For example, in 2006, NOAA led a United States Climate Change Science Program (CCSP) Synthesis and Assessment Report that examined the apparent discrepancybetween changes of temperature observed in the atmosphere and those observed at

[1] Myneni, R.B., C.D. Keeling, C.J. Tucker, G. Asrar, and R.R. Nemani, 1997: Increased plant growth in the northern high latitudes from 1981-1991. Nature, 386, 698-702.
[2] Elsner, J.B., J.P. Kossin and T.H. Jagger, 2008: The increasing intensity of the strongest tropical cyclones. Nature, 455, 92-95.

the Earth's surface[3]. The discrepancy was largely resolved by carefully comparing competing CDRs, thereby highlighting the importance of having CDRs calculated using multiple approaches and multiple observing systems. These comparisons enabled a confident statement of certainty, something that was impossible to do without multiple CDRs for essentially the same climate variable.

Based on these and other studies, the World Meteorological Organization, National Research Council, CCSP, Global Climate Observing System, and other noted authorities have increasingly called for a comprehensive CDR program engaging multiple teams of scientists using independent observing systems to develop CDRs. The Strategic Plan for the CCSP and the Global Climate Observing System Plan (developed internationally with U.S. leadership) have identified 44 Essential Climate Variables (ECVs) for which CDRs can and should be developed[4]. Due to the massive amounts of new data that will be generated following the launch of NPP and the series of operational NPOESS satellites, preparatory work is required to assure climate research-quality processes and data ingest capabilities are in place so these new data can be exploited for climate change work as soon as possible.

The Challenge of Data Stewardship for Climate Data Records

For decades, NOAA has worked with NASA to develop, design, test, launch and maintain operational polar-orbiting and geostationary weather satellites. NASA has complemented NOAA's operational series with research satellite missions to test advanced systems and breakthrough technologies while acquiring critically important observations to improve our understanding of the global integrated Earth system, including discoveries on mechanisms causing changes in Earth's climate. Increasingly, the international community has flown additional environmental satellites. The cumulative investment in these satellites has been tremendous, and the payoff continues to be realized long after their mission lifetimes because of past and present data archive policies that allow for subsequent development and analysis of CDRs.

Across this diverse array of satellites, technological advances led to epic jumps in the quality, quantity and types of space-based measurements of Earth. Such improvements were often countered by the effects of an unforgiving space environment and changes in temporal and spatial sampling, resolution, orbital configurations, and calibration methods. Moreover, some satellite systems suffer premature disabilities, and all sensors degrade continuously once in orbit. The end result is our satellite data archives are now filled with an expansive patchwork of data which, while invaluable, were collected by many disparate sensors and platforms using different methodology and operating in different stages of health; this is one of our major data stewardship challenges.

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[3] U.S. Climate Change Science Program, Synthesis and Assessment Product 1.1 "Temperature Trends in the Lower Atmosphere, Steps for Understanding and Reconciling Differences", April 2006.

[4] List of Essential Climate Variables provided in Appendix

Coping with the sheer volume of data from existing and planned satellites, along with the considerable ancillary data necessary to produce quality CDRs, is also a formidable challenge. Providing adequate data stewardship and access to these massive multi-petabyte archives requires comprehensive stewardship and information systems, such as those being operated by NOAA's National Data Centers. Data stewardship enables scientists and other users efficient and effective access to a variety of comprehensive data sets for CDR development and use.

NOAA's CDR Program

It is a privilege to report to you today that over the past two years, NOAA and NASA have been working on a coordinated interagency solution to develop and sustain CDRs[5]. Through this new initiative, as part of an effort to recover capabilities removed in the 2006 restructuring of NPOESS, these agencies defined a systematic program for identifying and transitioning the mature techniques from NASA's Earth Observing System (EOS) and other research programs into NOAA operations.

Thanks to satellite climate sensor and CDR funding in the 2009 American Recovery and Reinvestment Act, NOAA will begin to implement its part of the program which includes harvesting mature research technologies and applying them to decades of archived satellite data. Further, NOAA will continuously expand the range of CDR variables for climate change and extend the resulting CDRs using U.S. and international current and future satellite observations, including those from EOS, NPOESS and NPP.

To most rapidly facilitate integrated analysis, NOAA is focusing its early CDR development on environmental variables, which comprise critical components of the Earth's climate. For example, NOAA is currently reviewing proposals that would support advancements in understanding and modeling the Water and Energy Cycles. These are the climate system components, which impact lives, jobs and investments on a daily basis. Our ability to effectively mitigate and adapt to global climate change depends on our understanding of these components of the climate system. In future years, NOAA will focus on other key climate components, such as the Carbon Cycle.

Given the unique knowledge and extensive experience required to develop high-accuracy CDRs, NOAA will largely execute its program through competitively selected experts in academia, industry, non-profits, NOAA Cooperative Institutes, and other Federal agencies. NOAA will work to ensure that community knowledge gained through state-of-the-science research programs, such as NASA's EOS, is captured and incorporated into NOAA operations.

NOAA will also be upgrading its world-class data archive and access systems. Indeed, keeping up with the sheer volume of data coming from existing and planned satellites – along with the ancillary and validation data – that are necessary to produce, maintain and distribute CDRs requires comprehensive stewardship systems. NOAA is currently operating and continuing to

[5] The Joint NOAA/NASA Working Group for Sensors and Climate Data Records for NPP and NPOESS reporting to the NOAA Assistant Administrator for Satellites and Information and the NASA Headquarters Director of the Earth Science Division

develop its Comprehensive Large Array-data Stewardship System, which will provide the information technology necessary to support NOAA's CDR Program, among other programs.

The enduring success of the Nation's CDR activities will require sustained involvement of NOAA, NASA, and USGS, among others. NOAA will transition mature research into operations and leverage new CDR research methods and integrate new observing technologies from other agencies to help ensure the Nation's CDRs are well maintained and able to provide authoritative records of Earth's changing climate. Plans for future climate sensors to be carried on satellite systems should require consideration of CDRs to ensure continued and effective use of climate measurements.

Conclusion

There is no question that significant climate change information is currently embedded in the world's archived satellite data sets. Given the length, breadth, and global nature of these data, it is not an exaggeration to state these data contain valuable climate change information that cannot be accessed from any other sources. Although the disparate types and states of these data provide a challenge for developing CDRs, NOAA is now embarking on a comprehensive, systematic, and sustained effort to unleash the potential of these data from past, present, and next generation operational satellites to inform the Nation about ongoing and future climate change. Through this effort, our Nation will be taking a key action to improve its resilience to climate change and variability, maintain its economic vitality, and improve the security and well-being of the public for generations.

Appendix. U.S. Climate Change Science Program's Essential Climate Variables[6]
The table provides a summary of "State" and "Forcing/Feedback" variables for the major components of the Earth system. It is adapted from: 2003 Strategic Plan for the U.S. Climate Change Science Program, Chapter 12, Observing and Monitoring the Climate System, available at www.climatescience.gov and published by the U.S. Climate Change Science Program, Washington, DC 20006. Only measurements identified for space-based instruments are shown here. Many of these variables require *in-situ* observational networks to ensure reliable and validated retrievals from space-based sensors.

(1) Atmosphere

STATE VARIABLES	EXTERNAL FORCING OR FEEDBACK VARIABLES
• wind • upper air temperature • surface air temperature • sea-level pressure (I) • upper air water vapor • surface air humidity/water vapor • precipitation • clouds • liquid water content	• sea surface temperature • land surface soil moisture/temperature • land surface structure and topography • land surface vegetation • CO2 and other greenhouse gases, ozone and chemistry, aerosols • evaporation and evapotranspiration • snow/ice cover • shortwave and longwave surface radiation budget • solar irradiance and shortwave/longwave radiation budget

(2) Ocean

STATE VARIABLES	EXTERNAL FORCING OR FEEDBACK VARIABLES
• upper ocean currents • sea surface temperature • sea-level/surface topography • sea surface salinity • sea ice • wave characteristics • ocean biomass/phytoplankton	• ocean surface wind and wind stress • incoming surface shortwave radiation • downwelling longwave radiation • surface air temperature/humidity • precipitation (freshwater/salinity flux) • evaporation • freshwater flux from rivers and ice melt • organic and inorganic effluents (into ocean) • biomass and standing stock • coastal zones/margins

[6] The international Global Climate Observing System maintains a similar list as applicable to the United Nation's Framework Convention on Climate Change.

(3) Terrestrial/Cryosphere

STATE VARIABLES	**EXTERNAL FORCING OR FEEDBACK VARIABLES**
• topography/elevation • land cover • leaf area index • soil moisture/wetness • soil structure/type • vegetation/biomass vigor • water runoff • surface ground temperature • snow/ice cover • subsurface temperature and moisture • land use • lakes and reservoirs • rivers and river flow • glaciers and ice sheets • water turbidity, nitrogen, phosphorus, dissolved oxygen	• incoming shortwave radiation • net downwelling longwave radiation • fraction of absorbed photosynthetically active radiation • surface air temperature and humidity • albedo • evaporation and evapotranspiration • precipitation • land use and land-use practices • deforestation • human impacts—land degradation • erosion, sediment transport • fire occurrence • volcanic effects (on surface) • biodiversity • Earthquakes, tectonic motions • coastal zones/margins

Mr. MOLLOHAN. Thank you, Dr. Karl. Dr. Busalacchi.

Dr. BUSALACCHI. Yes.

GAPS IN SATELLITE DATA

Mr. MOLLOHAN. Earth Observing Satellites currently flying, Terra, Aqua, and Aura, are all now beyond their design life. The last of the NOAA polar orbiting environmental satellites has been launched and there are only a few defense meteorological satellites awaiting flight. A major shift is coming with the long delayed NPOESS satellite series. Gaps in data and shifts in instrument capabilities have the potential to disrupt the climate record. Will the MIS instrument on NPOESS provide continuity in microwave imaging of the oceans, extending the data records from the special sensor microwave image, SSM/I, flown on the DMPS satellites? And how will other changes in available microwave measurements affect oceanographic research? For the record.

Dr. BUSALACCHI. So the first part of your question speaks to this need for national strategy. Right now, the ad hoc mode of one sensor after another, so we really have not between the agencies, NASA and NOAA, developed this sort of joint strategy where these missions need to be planned ten, twenty, thirty years into the future.

Now specific to the issues with respect to SSM/I and the continuation there, first of all the NPOESS series will continue the SSM/I, what is known as the DMSP series of satellite observations for things like sea ice concentration, atmospheric water vapor concentration. So that is relatively secure. One of the pending problems is a sensor called AMSER on Aqua, which does all weather sea surface temperature. This is a sensor that sees through clouds. The long history of sea surface temperature retrievals going back to the late 1970's, as I said, is an infrared technology which cannot see through clouds. So this C-band, or it is in kind of the six gigahertz range, this C-band technology is on Aqua right now. And as you alluded to, Aqua is on sort of its last legs. It may last two or three more years, and it may end within the next couple of years.

Then we have a gap and not until about 2012, there is another AMSER-type sensor on the Japanese platform called GCOM. So we have a potential gap there between, of about four years where we may not have any all weather sea surface temperature until the first MIS sensor, which is being designed but is still not cast in stone. The design for the sensor is still not cast in stone for this all weather capability in 2016. So the critical gap is this all weather sea surface temperature capability that we may have a problem with at around 2010 or so.

STATE OF CLIMATE DATA COLLECTION

Mr. MOLLOHAN. Dr. Karl, summarizing the status of data collection, where do you feel really good about it and where do you think we really need to pay attention to it?

Dr. KARL. Well, thank you for that question. I am very pleased, because this is the first time we have actually been able to have a formal program for what I described as climate data records. And I am actually feeling good that this is a new opportunity for NOAA to treat data from satellites uniquely different than what we have done in the past. Before we processed it very quickly to produce weather forecasts. And that was our primary motivation and goal. Now today, formally, we are saying the agency is recognizing the value of these data for looking at long term and shorter term climate variability and changes. So I am feeling pretty good about that from the standpoint of it is going to encourage important scientific data stewardship in the agency that will actually transcend the agency. Because we are actually recognizing there is a lot of information beyond NOAA itself that we want to build on and leverage. I think the program that we have set up is going to do that. So I am feeling pretty good about that.

There are other areas where there is still quite a bit of work that we have to worry about, anticipate. One can imagine in the future as we have petaflop computing capability readily available to us we are going to be involved in producing climate data records. We are also at the same time ingesting all of the other data that we are receiving. Some of the important questions that will be asked will be requiring us to integrate these data, both the model data, the observational data, both from satellites and the climate data record program. And so it clearly, we will really have to think hard and strong in out years as to how these rapidly growing data volumes can be made easily accessible. And we will have the infrastructure necessary to move them around the country as rapidly as possible.

DATA ACCESSIBILITY

Mr. MOLLOHAN. And I would think meaningfully accessible. I mean, just thinking about the volumes of data, the historic data, and I want to ask you about that. But combined with the contemporary data in all the different ways it is coming down. It mean, just think about it. We have had testimony here, we are doing winds, and temperatures, and ice melt rates. I mean, it is a mind boggling, massive amount of data. And to retrieve it and capture it meaningfully, and store it, and then begin managing it in a way that can be manipulated and extracted for meaningful purposes. Where are we in that? Do we have the systems? Do we have the capability? And to what extent is data being extracted, I suppose selectively or however, and useful, and how far do we need to go? What do we need to do in order to achieve those goals?

Dr. KARL. One of the things that is absolutely critical, clearly the infrastructure of the systems is undoubtedly you cannot do without. Before I head in that direction let me just say through the U.S. Global Earth Observing System Program, and its international geocomponent, we have worked cooperatively with all the agencies to ensure that when we actually talk about building new data systems we really think about it in terms of, and I hate to use these acronyms, but service oriented architecture approach. But simply, that is a short way of saying we want to build systems so that it is very simple for each of the agencies to link together their software, what they already have available, what they have already invested tons of manpower and dollars in, and be able to link it together in a way in which we all develop on agreed upon standards. And so I think that process is really critical. And I am encouraged to see a lot of cooperation among the agencies there.

But critically, one needs systems then to be able to store the data and transport the data. Certainly the capability of the so-called Internet II, very, very important. We are finding in our data center increasingly the requests for data, large volume data from, we have a different suite of users. One suite are the academic, research types and they want as much data as you can send out to them. The other equally important user, in fact in some cases a far greater number of users, want data in bite size nuggets that they can digest because they are actually wanting to use it for practical problems. And so the real challenge is to figure out how in these systems we can serve the whole spectrum of users out there. And that is where the systems have to work with the user requirements, and the people who were actually designing the software, and the scientists who are actually helping to understand the data, have to really keep these two goals in mind. And I think that is sometimes where we often find that maybe we can do a better job from the standpoint of trying to think about systems that are as flexible as possible in that regard.

Mr. MOLLOHAN. Well, bring the Committee up to date and start from the beginning. We have had EOS and we have had EOSDIS. And the distribution systems for, is that the beginning? Or where are we with regard to satellite data? Where did we begin——

Dr. KARL. We actually began, we had in NOAA something called the satellite active archive. And it was from our agency's standpoint, it was very tailored toward people who were experts in satellite usage. And so the formats that you would get would be very unique. Few people could deal with them. And so the limited use of satellite data that we have in our records was largely due to that.

EOSDIS came and said, "We are going to serve all the users from kids in grammar school to senior level researchers."

Mr. MOLLOHAN. Which was a NASA program?

Dr. KARL. It was a NASA program.

Mr. MOLLOHAN. So they were going to, and are, I assume, bring the information down, distributing it to different——

Dr. KARL. Sectors.

Mr. MOLLOHAN [continuing]. Computer or data centers, by sector, and then manipulate the data and make it accessible out of those centers. So where are we with that? Is that the right architecture for today and for the future? And where should we go from there?

Dr. KARL. Well, you know, I think that certainly the architecture that NASA used was very appropriate for, remember they were looking at their specific missions. And so they were developing responses to the particular missions they have. For what we are trying to do in NOAA, our architecture is going to have to combine both the in situ, the historical data, as well as the modern data. And so, when we look at our architecture, the way we are trying to envision this is to have data centers that are equally complementary, but that can back up data from, for example, if one data center went down, you would not even notice it as a user because you could pick up data from another data center. And so our approach is to have redundancy in our system. But that we would have centrally located a couple of hubs that would have comprehensively all the data.

Then in terms of community of researchers that we work with, they would store data that they would be working with, but we would want them to, after a certain point in time, document what they have done, be able to upload it to the central hub, so that we would have the documentation. We would be able to go back and retrace the steps that they did to correct the data, develop the climate data records. So our architecture is one in which you might think of it a little bit in the way of spoke and hub.

Mr. MOLLOHAN. I want to follow up a little bit with that on the next round. But Mr. Ruppersberger?

RESOURCES FOR WEATHER AND CLIMATE PREDICTION

Mr. RUPPERSBERGER. Thank you. The issue of, first, basically you are saying that the satellite is clearly the best resource that we have to help you to predict the weather? You talked about the oceans, I have heard both of your testimony. But what is the best resource you have? Is it satellites?

Dr. BUSALACCHI. I would say for monitoring and prediction, you cannot say that there is just one——

Mr. RUPPERSBERGER. Busalacchi, right?

Dr. BUSALACCHI. Busalacchi.

Mr. RUPPERSBERGER. Busalacchi.

Dr. BUSALACCHI. One best technology. You actually need the combination of both satellite observations and in situ observations. Each have their own inherent strengths and weaknesses. So we need sort of a combined approach. So I will not say that satellites are the best because they have deficiencies, they also have strengths. So it really needs to be this coordinated approach. I would say in the past we have been going down two tracks that have been parallel. We have had the in situ, or ground sea based observations. We had the satellite observations. We need to start bringing them together, and integrating them, and designing, again, that is part of this national strategy I was alluding to. Bring together the strengths of both sorts of measurement technologies.

LONG-TERM STRATEGY FOR SATELLITES

Mr. RUPPERSBERGER. Well, you know, the issue that I think you are saying, you are loud and clear, is that we need a long-term plan. That is step one. And it is good news that, I hope, that we are not into science, so we can deal with science and what the conclusions of science are and not idealistic issues that are out there. So that is going to help, I hope. So we need to put a plan together.

But we are appropriators. We have to make decisions on priorities, on what we spend and what we do not spend. Satellites are extremely expensive, as you know. And you have a three-way competition, the way I see it, between DOD intelligence, and then NASA, and then NOAA with NASA. And what I do not see, and that needs to be developed, it seems that everybody, each one of those entities wants to have their own, they want to own their own, especially the Department of Defense. And that probably goes back in culture or whatever. But, you know, we just do not have the money for all of it anymore. And what I think, when you are developing a long term plan, there are certain things that the intelligence community are not going to give you. They might help you, but they are not going to give you. But there might be other things that they can. And I think there has got to be from your side, the scientists' side, a lot of communication and negotiation on how you can take advantage of these satellites that are up there to protect our national security. And yet use it also, because weather is part of our security and our national security. It is not about the bad guys coming in, it is about weather and, you know, as you know, and you have seen with Katrina and in other areas.

And I would like to know if you have had any conversations? Do you agree with my premise, that there needs to be more cooperation? Because I think in the end, when it comes down to who is going to get what, it is going to be DOD first, intelligence second, and you all third. And we just cannot. And even with NASA itself, there is just too much duplication of effort. Too much money spent. And now with cybersecurity out there, and we kind of know that we have been attacked on a regular basis, you know, with other countries on the cyber issue, there is just too much out there not to have a plan and to be involved. Could you please comment on my comment?

Dr. BUSALACCHI. Sure. So clearly, there needs to be better definition of the roles and responsibility amongst those three or four parties that you described. In our NPOESS experience we saw front and center the problems with once you get beyond weather. So there clearly is continued opportunity for coordination on the weather front across DOD, NOAA, and NASA. And problem with the NPOESS came when we came to climate because, as I said, there are these unique requirements for climate above and beyond weather. Now if we can——

Mr. RUPPERSBERGER. And weather can be used by DOD, too, so that——

Dr. BUSALACCHI. That is right. So weather, I think, is manageable. Where some extra effort needs to be made is for the climate sensors, because climate is not high, in the past has not been high. It is gaining greater priority within the DOD.

Mr. RUPPERSBERGER. Weather kind of changed World War II, did it not?

Dr. BUSALACCHI. Right now, and climate is becoming a national security issue with respect to vulnerable areas overseas. I will defer to Tom.

INTERAGENCY COOPERATION ON SATELLITES

Mr. RUPPERSBERGER. But what I want to hear, if you can answer this, is there an effort, ongoing effort, is there a negotiation going on between those three entities?

Dr. KARL. I can mention, I actually can bring this issue a little bit higher from where I am coming from, from this climate data record perspective. The value of that program is to try and look at all the assets that are out there, and to make silk out of a sow's ear in some respect. From the standpoint of many of these instruments that have been put on satellites have not been put up there to measure climate change and variability. They have been put up there to do other things. That does not make them ideal to monitor climate. But there is value, there is information there, that we want to be able to make use of.

That discussion, I think, is going on not only amongst the agencies. I know I have spent the last couple of years and many meetings with my NASA colleagues and some of my other colleagues in other agencies, talking about how we can best look at the past data and put together the best climate data records. But also, this discussion is going on internationally among the scientific community. Global Climate Observing System, there is a number of documents that talk about look at the same essential climate variables that we have identified in the Climate Change Science Program strategic plan, trying to identify how we could best go about coordinating this internationally, and put together a coordinated effort to produce the best information we can have about climate change.

Now, that is not quite the same as saying, you know, what is it that we need in the future? There are other groups, there is a Committee for Earth Observing Satellites, that are looking at internationally what each nation is bringing to the table. And, of course, we are represented by more than NOAA and NASA and all of our space agencies.

So there are discussion at that level that are taking place. And I will admit this is not an easy problem and I think you raise an extremely important point.

Mr. RUPPERSBERGER. One of my suggestions will be clearly we have to emphasize a plan. There needs to be, I mean, I chair the Technical and Tactical Committee on Intelligence, which when I finish I am going to go down and have a hearing in that regard. And I know that there is a lot of play now between the intelligence community and the DOD. And where there is duplication of effort, again, wasting money. And believe me, the money is not there so somebody is going to be hurt and I think it might be you.

Another suggestion I have, too, when I asked you the question I did it on purpose. You know, what are your priorities? And you said, well, satellites is just one of them, you have another one. I do not want you to change your answer because that is a good answer and that is a scientific answer based on your research and conclusions. But I would emphasize how important that the satellites are, because you are fighting for that money against intel and DOD right now. Okay? Thank you.

Mr. MOLLOHAN. Thank you, Mr. Ruppersberger. Mr. Serrano.

OCEAN HEAT CONTENT AND HURRICANES

Mr. SERRANO. Thank you, Mr. Chairman. Dr. Busalacchi, in your testimony you stated that monitoring the heat stored in ocean eddies is also providing new insights as to how upper ocean heat content can lead to hurricane intensification, as in the case with Katrina. Was this something you knew prior to that? Or something you picked up after you studied the data? And either way, can it lead to helping us predict what is going to happen in the future?

Dr. BUSALACCHI. Thank you for the question. Prior to Katrina, clearly we recognize that the atmosphere and the ocean is coupled. But specific to this intensification of Katrina, it was after the fact when studies were done looking at the track of Katrina compared with the satellite altimeter data that showed this warm blob of water in the Gulf of Mexico. That is now leading to improved hurricane models that are much more coupled between the atmosphere and the ocean, and have this feedback between the atmosphere and the ocean. So that is leading, as a result of this sort of retrospective analysis, to increased forecast skill and studies of intensification for the hurricane problems.

INTERNATIONAL COOPERATION ON SATELLITES

Mr. SERRANO. To both of you, I noticed you mention the international community. And I am always interested in knowing what role our foreign policy plays into these issues. When you say the international community, does that include nations that we may not have good political relations with? I mean, like, do we deal with Iran? Do we deal with Cuba when it comes to issues of climate change?

Dr. BUSALACCHI. Our best success stories for satellite climate studies are our friends and partners, France, Japan, Brazil, India. These are great success stories. Germany as well, great success stories.

Given the budget challenges, I think it really is reasonable to be going down this path, a partnership approach. But it has been our historical friends.

Mr. SERRANO. Okay. But are we allowed? Does our government allow you to sit at the table with countries we don't have a relationship with when it comes to dealing with these issues? I always wonder if we——

Dr. BUSALACCHI. In an international forum?

Mr. SERRANO. Right.

Dr. BUSALACCHI. We are allowed to sit with our colleagues from some of the nations you mentioned. But there are restrictions with respect to any exchange of technology. The discussions are all within papers that have appeared within the peer review literature. That is the level of the discourse.

Mr. SERRANO. So if you see something approaching a country that we are not crazy about, you are not at liberty to tell them there is something coming your way?

Dr. BUSALACCHI. I don't deal with that sort of prediction.

Mr. SERRANO. Or are they not at liberty to tell us something is coming our way?

Dr. BUSALACCHI. That is correct.

COOPERATION ON CDR'S

Mr. SERRANO. Okay. Dr. Karl, in reading your testimony, I was impressed with the tremendous challenge that you confront as you seek to convert raw material, sensor data into climate data records, CDRs as you said. I thought they were rewritable CDs you were talking about, the CDRs or recordable CDs.

In your statement you stated that CDRs that are not developed using multiple approaches and multiple satellite and earth-based observing systems are often problematic. As you move forward with this important project, do you foresee difficulties with getting this necessary cooperation on multiple fronts? It seems that you will not only need cooperation across agencies, but perhaps even with other governments in order to successfully use this information, which somehow a little bit touches on my prior questions.

Dr. KARL. No. In fact, I have a story I can tell you why this is important, and why I think it actually can work and has worked in the past.

We had an issue a few years ago where we had two—it first started off with one group trying to calculate from satellites what the change in atmospheric temperature had been since 1979. And in their published reports there were error bars put on, you know, how good they thought they could do. And then we had another independent group use a slightly different approach. And they published papers in their error bars. And their error bars didn't—when you overlap the changes that they both thought were occurring, they didn't overlap. And their error bars didn't overlap.

And so the question was well who could you decide which was right and which was wrong? Because there was many, many papers written both defending the techniques that were being used. It wasn't until a number of other groups using slightly different approaches and other measurement approaches, not only satellites but in-situ data that we actually got to be able to really understand what the air structure was, how far we could go in terms of doing an analysis.

And in the end, just recently there was a paper published showing that right now we think we truly do understand what our limits of certainty are and be able to tell you—being able to tell you what the changes in tropospheric temperature have been since 1979, because we have had multiple groups looking at it independently using satellites, using in-situ data. So I think that is—that is an example why we think it is really important to have multiple approaches using multiple observing systems.

And I think the cooperation comes in this business that we are in, there is a tremendous drive by scientific teams to try and probe as deeply as they possibly can. So if there is any possible way of looking at data that people might not have thought of before to look at, they really push the envelope if you provide the encouragement and the resources for them to do that. And that is why I am so excited about the CDR program, because I think it does offer us an opportunity to encourage that kind of exploration that perhaps we might not otherwise have gotten.

Mr. SERRANO. And how often? You have an example, but is this is a common occurrence of NOAA agreements?

Dr. KARL. No agreement tends to be a common—I will give you another example.

Mr. SERRANO. It sounds like the U.S. Congress.

Dr. KARL. No comment on that. Hurricane intensity is a very important topic. You know, are hurricanes becoming more intense? And we have had a flurry of papers over the past number of years talking about whether you could discern from the data and how you could discern changes. We have got in-situ data. We have data that hurricane centers, both our hurricane center and the Pacific Hurricane Center, one by Japan, one by Australia, have tried to make their best estimate about hurricane intensities. And, of course, the procedures have changed over the years.

So the question comes in are those data really climate data records stitched together in an appropriate way? Probably not. But you have got a number of individual research teams looking at that. But then recently we have been able to encourage them to take a look at the satellite data. And what would you get if you objectively compiled the satellite data.

So we have stitched together a number of geostationary satellites, because the advantage of geostationary satellites is they are always looking at the same spot. And hurricanes don't go up so far to the poles that we will miss them, like you would have with the polar orbiter. You would want to have a polar orbiter if you had something important going in the poles.

But in any case, there has been a number of other teams that have looked at these satellite data. We have helped them reprocess that data. And we are finding some very interesting confirmations. Differences in the rates of trends about things like hurricane intensity. Confirming, yes, we are seeing some increase in hurricane intensity since 1979, 1983.

The next step is okay, is that linked to increases in sea surface temperature? Is that linked to any of the anthropogenic changes we have seen? Those are other questions. But you can't even begin to answer those questions without having the basic data to start out with.

SEVERE WEATHER AND CLIMATE

Mr. SERRANO. Mr. Chairman, in closing, this reminds me of a question I think I asked yesterday or the day before. I seem to remember when I was much younger that it didn't seem like the weather was so severe. So is it that the weather has gotten worse or is it that CNN and Fox can give it to me live with pictures right there with the reporter being blown away by the wind. And the answer I think was a little of both. But you say that you have noticed increased intensity since 1979 or so?

Dr. KARL. And I agree with you. It is a little of both. In fact, there was a report that the Climate Change Science Program, inner-agency program—NOAA led a report that we released last spring called "Weather and Climate Extremes and the Changing Climate."

And depending on the kind of weather and climate extreme you look at, what you have said, Mr. Serrano, is exactly right. For example, tornado frequency. You know, we are able to spot those much better today than ever before. And if you look at the raw numbers, you can be pretty much deceived.

For some of the other aspects of climate extremes—sorry about that, some of the other aspects of climate extremes, that is not the case. And things like heavy downpours, there is very good evidence now that we are seeing an increase in heavy downpours in this country and other countries.

And it is very important, because it has important implications for infrastructure development, things of culverts in terms of runoff, flooding of basements, that kind of thing.

Mr. SERRANO. Oh, thank you. Thank you, Mr. Chairman.

Mr. MOLLOHAN. Thank you, Mr. Serrano.

Mr. Fattah.

CDR DEVELOPMENT

Mr. FATTAH. Thank you, Mr. Chairman. Dr. Karl, to the best that I can understand this in layman's terms is that there is a lot of data that has been collected over the last 50 years from satellites. And even though they weren't up there necessarily looking at climate change, this data could be from an empirical basis, very helpful in terms of trying to quantify what exactly is going on.

So you are in pursuit of this information. This is the CDR program now.

Dr. KARL. Right.

Mr. FATTAH. In this stimulus package, we funded both climate sensors and this—in this effort that you are involved in. Can you give the Committee a sense of how far along you are going to be able to go with that appropriations?

Dr. KARL. Yeah. I can tell you we actually have a list of how many climate data records we think we could actually produce from the existing set of sensors we have out there. And the list is about a hundred or so. That is quite a number. And the cost of—you know, if you look at what is the average cost of doing a climate data record, it is a couple of million dollars.

And then there is also—you have to be able to sustain that, because you want to make sure that, you know, year after year you are able to update. And that cost is, you know, not the same amount as the up-front costs, but it is a significant fraction to continue those climate data records.

So, you know, you can do that math. And you can see that this is a great start. But it is something that we will certainly have to sustain if we want to look at that entire list.

And I should say that list was derived from this agreed upon set of essential climate variables from which there is—the next step further, for example, I gave you the hurricane example, hurricane intensity. Hurricane intensity is not really one of the essential climate variables. But we think it is pretty darn important. But it is derived from things like cloud information and derived from winds which are an essential climate variable.

So that is why that list of 44 is a little bit larger when we look at how many we think we could actually get.

CLIMATE DATA MODERNIZATION

Mr. FATTAH. These data archives, I assume a significant number of them are accessible. Are there others that are not assessible for non-financial reasons?

Dr. KARL. Yeah. We have something called a Climate Data Modernization Program. And we are trying to make as much data as possible computer accessible. And simply because there are still paper records, we actually—believe it or not—are still getting punch paper tape, 15-minute precipitation measurements from 2,000 sites that we have across the country. These are 15-minute rainfall data, which are extremely important in terms of trying to measure rainfall intensity. So as part of the Climate Data Modernization Program, we are taking those punch paper tapes and actually converting them to something digital that we can use on computers.

So the answer is yes. There is data out there that were not accessible. But through the Climate Data Modernization Program, we are trying to make those accessible.

Mr. FATTAH. It sounds like something like hanging chads or something.

Dr. KARL. That is pretty close, pretty close.

Mr. FATTAH. Let me thank both of you for your testimony. Thank you, Chairman, for hosting this hearing.

Mr. MOLLOHAN. Thank you, Mr. Fattah.

Mr. SERRANO. Do you think we could ask for a weather report for the Phillies, Orioles, and Yankees opening days?

Mr. MOLLOHAN. You can ask any question you want, Mr. Serrano.

Mr. FATTAH. Whatever the weather, let me just assure the gentleman from New York, the Phillies are the World Series champions. And we intend to retain that honor.

Mr. SERRANO. Just remember 26 World Series championships.

Mr. MOLLOHAN. Stop. Mr. Bonner.

Mr. BONNER. Thank you, Mr. Chairman.

I always regret when I am late to a panel, because you are half way through your testimony. And you have already answered a round of questions. And I am always embarrassed when I have to ask the same question that you have answered three times. So if this has already been asked, let me apologize.

SATELLITE DATA & HURRICANES

As I have asked the previous panel earlier today though, I think I am the only member of this Subcommittee who lives along America's Gulf Coast in Mobile, Alabama. So first of all, thank you for what you do to help us better understand bad weather, especially hurricanes, better prepare for them, and get a better handle on what impact that we have globally and certainly here in this country might have in terms of connection to bad weather.

In answer to Chairman Serrano's question about whether it is that we know more, whether it is that we are having more information presented to us, I tell you, there is certain weather reporters from the Weather Channel that when they show up in your backyard, you want to get out of there. That is the warning signal that you are waiting on to know that it is time to evacuate.

And I also think it is important. We don't say enough thanks, those of us from Louisiana, and Mississippi, and Alabama, and Florida, and Texas to thank the American people, not only for the work that you all do, but also for the generosity of the American people in time of a hurricane. Katrina being the good example, 90,000 square miles, hundreds of millions of dollars that came in to help.

But my question is this. You said in your written testimony, Dr. Karl, that researchers at NOAA's National Climate Data Center spent four years carefully merging and intercalibrating a patchwork of data from 29 geospacial satellites, both U.S. and foreign, to develop a CDR to facilitate efficient global analysis of hurricanes and go on to discuss that. The panel earlier this morning suggested that we may see one meter rise, because of the melting of the ice over the next century that could have an affect on beach erosion. It could certainly have an affect on hurricanes.

But based on your work over the last few years, what would you anticipate that we could look at over the next few years? Over the next century seems so far away for most people. But we are going to be coming into hurricane season in just a few months. And more importantly over the next few years as communities discuss maps, and rebuilding, construction code, and other things that we seem to have more control over, based on your knowledge and data, what are some of the things that we could anticipate and look forward to or dread that might be just over the horizon?

SEA LEVEL RISE

Dr. KARL. Yeah. I can tell you, you have identified an interest—a topic that is of great interest to NOAA. And we have had considerable discussions especially recently. I will give you an example with the Governors of the coastal states talking about this very issue of sea level. And exactly the same issue that you raised there is concern for, you know, what should the long-term strategy be. But there is a near term and an immediate strategy.

And one of the things that I can tell you that NOAA is talking very seriously amongst the climate interests and our coastal interests is issues related to what we could bring to the table in terms of helping to develop, for example, a sea-level prediction system that would incorporate not only a tidal type of information that you have, but information about what we have available from expectations on global climate change, our capabilities with respect to storm surge modeling.

The key issue here is to try to tie that kind of information together. We have got a lot of very important individual pieces. Tying it together is the challenge right now. We have been engaged with discussions with USGS about this very issue. And part of the reason these issues come up also is we do these assessments. And you may have seen there was assessment recently from the Climate Change Science Program on sea-level rise. And they focused on the mid-Atlantic area.

But if you go and look at that report, you would recognize although there is a lot of good individual pieces of information we have, tying it all together is the real challenge. And I think that is an area that we have some potential. And so you say what could you look forward to in the future? Hopefully that will be an area we will be able to say more about in the future.

The interesting thing about tides, in sea level, is when you look at the short term, people certainly recognize storm surges and hurricanes have a big effect. But even the patterns of wind flow during certain times of the year will change the sea-level rise that we are measuring from tides in substantial ways.

So if you look on the East Coast and Carolinas, an October storm is much more devastating than an April storm, because of the prevailing wind patterns. But anyway, good question.

Mr. BONNER. Well, again, thank you for being the unsung heroes on many occasions. I have had the opportunity to call on you late at night on a Saturday or early in the morning on a Sunday and get information that was helpful to our Governor, and our mayor, and others to try to get information out to the community so that we could get people out of harm's way. So on behalf of all the wonderful people who work there, please accept our thanks.

Thank you, Chairman.

Mr. MOLLOHAN. Thank you, Mr. Bonner.

DEFINITION OF RADAR ALTIMETER

Dr. Busalacchi, tell the Committee what is a radar altimeter?

Dr. BUSALACCHI. A radar altimeter for me remains one of the most remarkable pieces of engineering for me. This is a technology we use to monitor and measure sea-level rise, as was just mentioned. We have been having these precise radar altimeter measurements going back to about 1992. But in simple terms, it is very much like the speed gun in a police car. Except this time the speed gun is orbiting 1,300 kilometers above the surface of the earth. It is measuring changes in sea level to a few centimeters.

So that is like standing here on the steps of the Capitol, pointing this speed gun down to Jacksonville, Florida, and measuring changes in the Saint Johns River to about one inch. So I continue to be amazed by the technology. In fact, technology then that allows us to measure sea-level rise on a global basis. But then with respect to Representative Bonner's question, have a better understanding of the regional changes in sea-level rise going into the future.

DEFINITION OF SCATTEROMETER

Mr. MOLLOHAN. What is a scatterometer?

Dr. BUSALACCHI. A scatterometer is another radar technology. This time you send down a radar pulse to the surface of the ocean. And you know when you look at the ocean or a lake and you see those little ripples, well those ripples get bigger and bigger based on the strength of the wind. And so how the radar is back scattered off these ripples tell us something about both the strength and the direction of the wind.

So that is how we measure global wind velocity. So that is what we use into our climate models for the ocean. But it has also proven to be—even though it is more of an oceanographic sensor, a very useful sensor and retrieval for marine weather and for improving hurricane forecasts.

And so that is one of these areas where we have technology that has been in place since about 1999. We have not secured the next generation of sensor. And I know NOAA is in active discussions with Japan, for example, to provide a follow-on sensor for hurricane prediction, extreme weather, and for climate predictions.

CURRENT STATE OF INSTRUMENTS

Mr. MOLLOHAN. That prompts the question are the instruments that we are using, these two instruments, are they adequate to today's capabilities for climate change and operational purposes?

Dr. BUSALACCHI. Very good question, sir. I would say for the global problem, the scatterometers and altimeters, that have technology of fifteen to seven years, they are adequate. But now when you speak to operational oceanography, and getting back again to

Mr. Bonner's question, when you start coming into the coastal zone, this class of the older technology does not have the resolution to get us to within 25 kilometers.

So these new sensors, as mentioned in the decadal survey, the extended ocean conductor wind measurement for—it is a scatterometer measurement. We can get within five kilometers of the coast. The surface water ocean topography sensor, which will get us closer into the coast for sea level, that is the next generation of sensors that I believe need to be put in place to continue the global scale but as we get into the coastal scale and operational oceanography. What we would call the combination between blue water, open ocean, and brown water, the coastal ocean. It is these next generations of sensors. They are going to be needed to get us closer to the coast and get to these more regional specifications that we need.

Mr. MOLLOHAN. Where are we in the development, and construction, and deployment of these new sensors?

Dr. BUSALACCHI. So these sensors, both of those that I mentioned, are in the middle tier of sensors recommended for the decadal survey. So they are slated nominally for 2013 to 2016. And Tom is better to speak to what the thinking is with the know with respect to scatterometers.

So the next generation of sensors, again, looking at least five years from now I would say.

Mr. MOLLOHAN. And will they be on line soon enough to provide a continuity of information?

Dr. BUSALACCHI. No. That is where there are some potential gaps for both the continuation of the altimeter and continuation of the scatterometer. Those are some serious issues where we may be at a point where we would have a gap.

GAPS IN ALTIMETER AND SCATTEROMETER

Mr. MOLLOHAN. What kind of gaps respectively?

Dr. BUSALACCHI. For altimeter we have the Jason-2 sensor up there now. It was launched last year. Nominal lifetime about three or five years. So this is the first time—this is about the third series of altimeters. The first time that an altimeter is up and we have not yet secured the follow-on altimeter. So we may be faced with a gap of several years.

And scatterometry, as I said, the QuikSCAT sensor was launched in 1999. It is on its last legs. So in that regard it is almost too late.

Mr. MOLLOHAN. So how do we accommodate those gaps? And what do we do about it being too late with regard to gathering the information that is necessary to get——

Dr. BUSALACCHI. Well, one is to keep our fingers crossed that the present sensors continue. So, again, that is not the best way to have a strategy.

Mr. MOLLOHAN. It doesn't sound very scientific.

Dr. BUSALACCHI. That is correct. But in all fairness, our NOAA colleagues have been in deep discussion with EUMETSAT, which is the operational arm that manages weather satellites in Europe, with respect to this Jason-3 satellite. But yet it has not yet been secured. And as I alluded to, NOAA has been under discussion with Japan with respect to a follow-on scatterometer.

Mr. MOLLOHAN. And how adequate are these measures?

Dr. BUSALACCHI. So the Jason–3 is the—would be the continuation of this global measurement.

Mr. MOLLOHAN. Yes.

Dr. BUSALACCHI. So that would continue the sea-level rise. This issue of heat content. But it won't get us close to the coast. So that is where we need this SWOT mission.

Mr. MOLLOHAN. Yes.

Dr. BUSALACCHI. Similarly, the discussions with Japan for the follow-on dual frequency scatterometer would continue the present class of scatterometer observations. But, again, it won't get us close to the—close as the decadal survey extended ocean and vector wind measurement mission would.

GAPS IN DATA FOR CDRS

Mr. MOLLOHAN. How important or significant is the gap or the lack of information with regard to our understanding of global climate change?

Dr. BUSALACCHI. This speaks exactly to the issue of climate and data records. Where a break in a climate data record—once it is broken, you can't replace that record. So, again, it is not the same as weather. So that is, again, to reiterate, all part and parcel need for the strategy so that we don't have gaps in the record. We don't have these uncertainties. Is there a mismatch in the record, because their gap is a result of new technology or is it a result of a geophysical change in the earth system?

Mr. MOLLOHAN. Dr. Karl, do you have a comment on this?

Dr. KARL. I think Tony's described the situation very adequately. What I would add is there are some things for which you cannot ever make up a gap. And there are other things where you have got ancillary measurements. And it certainly increases your errors, because you are going to have to do some infilling in ways that you might not otherwise want to do.

And I will bring up an example. And that is the TESIS instrument. This is measuring the total amount of energy from the sun. We have been doing that for 29–30 years now. And if we have a gap there, there is no way we can recover, because we can't do this any other way. And why that is so important, particularly when you are trying to understand anthropogenic climate change, if you have got this missing component. How much energy is coming from the sun? So what is causing climate change? Is it changes in the sun, or is it changes in what humans are doing?

So that is an area where there are some things where if we have a gap, there is just no way out of it. We are essentially starting over, because if you miss five years and begin to measure again, our measurements aren't good enough right now to say we can absolute measure the amount of energy from the sun. But we can do, and we have these overlap, stitch together these records.

For some of the other areas, it is certainly not ideal. But I will give you an example. If we can't get into the coast with an altimeter, the next generation of altimetry measurements, then you are stuck with relying on only tide gauges. And tide gauges are—you know, we don't have tide gauges everywhere along the coast.

So there are stop-gap measures. They are nearly not as satisfactory as one would like to do with next generation instruments. And especially kind of the questions that Mr. Bonner asked, you can address them, but not as well as you would like to.

NATIONAL CLIMATE SERVICE AT NOAA

Mr. MOLLOHAN. I may come back to this after votes. But I want to be sure to get this into the record. There is a whole lot of discussion in the last short period about the formation of a national climate service in NOAA. So a couple of questions about this, please.

How would operational requirements for satellite data change if monitoring climate were to become a NOAA mission? And how would land measurements be included?

Dr. BUSALACCHI. That is a great question. And I might put a preface there. As you know in Jane Lubchenco's testimony, she indicated that her intent was to form a national climate service, maybe comparable to what we have got in terms of a national weather service ready.

The important thing for us is that as Tony mentioned earlier this afternoon, we actually then will have a voice at the table when we are developing the requirements for future generation satellites. So that the climate instruments aren't looked on as a second cousin so to speak. So I think that will have an important change in terms of how we view the kinds of instruments we put up and the expectations of those instruments.

And the other area that I think is going to be extremely important for climate is we just talked about is the need for overlap and be able to project. And you can never view this perfectly. But for those instruments that are critical for continuity, where would we place our priorities for an overlap so that we could stitch together the records, which is a little different than the continuity, for example, for weather observers. If you are missing one day, you are out of weather forecasts for a day that are as high quality as what you had previously. If you miss a day in climate, you may find you are making some really difficult work for yourself ahead in terms of trying to observe the climate record.

So that will be important, the continuity, the kinds of things—the ways in which satellites are launched, their orbits, their calibration procedures, before they are launched. Their calibration during operation are fairly stringent for climate. They are certainly important for weather. But usually for climate, the stringency for calibration and accuracy are significantly higher.

So those would be important ways in which the change from the standpoint of land products, land is absolutely critical for understanding the climate. Just in the ocean is critical. But you can't understand what is happening to the climate system without the land components.

There are all kinds of products that have been derived from instruments like this long instrument we have had, the Advanced Very High Resolution Radiometer, AVHRR, to the next generation, or it was MODIS. And now we are going through VIRS. We would expect those products to continue, in fact, grow for climate purposes.

Mr. MOLLOHAN. Well, would the laboratories of the current ocean atmospheric research organization be distributed among the different NOAA services?

Dr. KARL. That is a great question. And it one of the things that as soon as Jane Lubchenco comes on, we are going to be talking about how her vision of a national climate service fits into some of the goals and principles that we have drawn from a number of reports that have been written. The Academy of Science just released two reports related to delivering better climate change information from the Climate Change Science Program. Another one is about betters ways of informing us about climate change decisions. A report by Dr. Busalacchi's working group to our Science Advisory Board on the benefits and challenges of various options for developing a climate service.

So we drew on all this information trying to put together some principles and guidelines and NOAA could follow. And we are looking forward to being able to brief Jane Lubchenco, Dr. Lubchenco, and explain to her what issues are at stake and how she would like to go forward.

Mr. MOLLOHAN. Thank you, Dr. Karl.

Dr. Busalacchi, do you have a comment on those questions?

Dr. BUSALACCHI. Certainly given what we have been doing with NOAA. I think from on one hand, a scientist's perspective, but also looking at some of the work we have been doing with assessing what users needs are of climate information. It is actually quite gratifying to seeing the government now seriously going down this path of the national climate service. And so it is very gratifying.

And then looking at these different models with respect to the land data, I think some of the architecture that we spoke of with NOAA is these sort of partnership approaches, federation approaches, NGO approaches that would sort of expand the disciplines: atmosphere, ocean, land. In order then they could support NOAA as a lead agency for a national climate service but in partnership with the other agencies that have an important stake such as NASA, USDS, Department of Agriculture, et cetera.

Mr. MOLLOHAN. Thank you.

Mr. Serrano.

Mr. SERRANO. I have no questions.

Mr. MOLLOHAN. Mr. Fattah.

Mr. FATTAH. We have a vote, Mr. Chairman. And I thank you. I have a few questions for the record about this gap and what we may do about it.

Mr. MOLLOHAN. Okay. Mr. Bonner, I think we have a few minutes. We have got 333 members who haven't voted if you have some questions.

INTERNATIONAL COOPERATION ON SATELLITES

Mr. BONNER. Just two quick follow-ups. And, again, it may be in your testimony. Forgive me if I don't see it. Who are some of our leading global partners that we rely on for satellites and for this type of information?

Dr. BUSALACCHI. Japan, France, Germany, Canada, Brazil. Our leading nations where we have enjoyed very strong equal partnerships over the past 20 years or so in this game.

Dr. KARL. And, you know, there is a list of—right now we are working quite closely with Korea with their GPS radio occultation measurements, which are another way to try and get us better information on about what is going on very high up in the atmosphere.

Quite frankly this job is one in which it really behooves to work closely with our international partners, because, again, we talked earlier about climate data records, having multiple looks at it, bringing together different sensors, different designs. It really makes a system more robust.

NOAA AND SCIENCE EDUCATION

Mr. BONNER. And then just one follow-up. And maybe you all are not the right people to post this question to. But under the Chairman's leadership, we have had many people over the last several weeks come in and talk about the importance of science education, math education, and how we are struggling with that here in this country. Many countries seem to be doing a better job. I am fortunate that the only state school, it is a residential campus, one of only 13 in the nation for high school, for math, and science, is in Mobile where I live.

I guess my question is what is NOAA doing to reach down? We are talking about needing to develop next generation technology and equipment that will help us. What is NOAA doing to reach down to young people at elementary, certainly middle school and high school, to get them to think about perhaps a career that might take them through your service?

Dr. KARL. Now that is a great question. And I think NOAA has participated in an inter-agency process here. Two years ago we published something called a climate literacy guidebook. And I think that is going to be updated here very, very quickly. We have worked with other organizations like the American Meteorological Society to try and encourage interests, particularly if you capture, as you say, the primary school and the younger children with an imagination that this is actually an exciting opportunity.

I also serve as President of the American Meteorological Society this year. And one of the things that I am always excited to see is support. NOAA supports numerous post-doctorate and doctorate candidates through graduate fellowships. And the quality of the candidates I see is pretty amazing.

But the challenges are far beyond what we have ever had in the past. And it really is important that we reach out. And I know NOAA, Dr. Louisa Koch, who runs our education program and NOAA, is actively engaged in this and has some very good ideas to try and bring this out more formally.

Mr. FATTAH. Mr. Chairman, since encouraged by you, let me try to——

Mr. MOLLOHAN. Sure, sure.

PARTNERSHIP WITH JAPAN ON SATELLITES

Mr. FATTAH [continuing]. Get my questions in right now.

You almost sounded like you were on this side of the table. You have referred twice to we are in the discussions with Japan about trying to deal with the gap. Just in terms of the global capabilities here, does that mean that unless Japan cooperates, that is, I assume sends up a new satellite, or gives you access, or gives NOAA access to data, that is the only way feasible to not have this gap?

Dr. BUSALACCHI. In the near term, that is correct. We won't have that. And even then that is in 2016, that particular mission.

Mr. FATTAH. So are those discussions going well? You can't comment? You don't know?

Dr. BUSALACCHI. I would have to defer to my NOAA colleague. That is in NOAA.

Dr. KARL. Yeah. And I can say that this issue comes up not only with Japan but with all the countries. We have engaged stridently with the international community about free and open data exchange. And that is an issue that is of vital importance to not only this country but other countries. Our policy in the U.S. has always been to provide our data freely and openly. You know, if there is a cost of sending tapes, you know, certainly that is involved in the charge. But——

GAPS IN SATELLITE DATA

Mr. FATTAH. But this is a 2016 launch?

Dr. BUSALACCHI. The second GeoComm would be 2016. That is correct.

Mr. FATTAH. Okay. So we don't have any other capacity by 2016 then to solve this on our own if we had to.

Dr. KARL. Unlikely.

Dr. BUSALACCHI. And that is why I will read it again. Hence the need for such a strategy.

Mr. FATTAH. Well, that is enlightening. Thank you.

CLOSING STATEMENT

Mr. MOLLOHAN. Let me ask my colleagues. You are just covering a series of questions that I wanted to cover. Just a few nuances that I think you could address. We could submit for the record. There are a couple of other questions for the record.

Mr. Serrano, Mr. Fattah, do you need to come back? I was going to ask you gentlemen to stay. Because we covered that and we can submit a couple for the records, we have got a series of eight two-minute votes. And then we vote to recommit. We won't be back until almost 4:00. So I think it is better to thank you all very much for appearing here today. We ask you to be responsive to some questions that we are submitting for the record that we surely will have.

And we most assuredly appreciate the good work that both of you do. We understand how important it is. We are beginning to understand how it all fits together. And we want to increasingly understand that. We can't do that without your expertise. And we want to be responsive and help you all do your job. And you are helping to lay a good scientific factual basis for us to consider appropriations.

So thank you for your appearance here today. Usually I would give witnesses a chance to sum up and say what they haven't said. But perhaps you can submit that for the record if you need to do it. Thanks so much for your appearance here today.

The hearing is adjourned.

Questions for the Record for Dr. Busalacchi

1. Will the VIIRS instrument provide continuity in ocean measurements from space that is adequate for climate change purposes, and how will the end of MODIS measurements affect oceanographic research?

The VIIRS instrument, as designed, would have provided continuity of ocean color measurements at an acceptable though far from ideal level. However, the actual performance of the first built instrument that is launching on NPP will not even meet its design specifications, particularly in the areas important to climate quality ocean color measurements. This means that the ocean color measurements from VIIRS on NPP will be far from research quality, and should MODIS measurements cease to be available prior to the launching of a full performance VIIRS instrument there will be a gap in the ocean color climate data record.

Satellites are not the only means of observing the environment.

2. Can you discuss the different roles and relative advantages and disadvantages of satellite sensing, aircraft observations, measurement buoys, and research cruises in oceanography?

Satellites provide global coverage and, of course, know no national boundaries. They can obtain high-precision measurements with the same instrument globally, spatial and temporal resolution depend on the orbit, but are generally lower than for sub-orbital. A continuous measurement record is possible but requires long-term planning and budget commitment. Geostationary platforms can provide high temporal resolution, but global coverage requires several satellites. Low earth orbit provides global coverage, but the repeat time at any one location is order of days. Satellites can be expensive and take a long time to build. However, if global coverage is required, the per pixel costs are far less than alternatives. As seen with the recent demise of OCO, they can also represent a single point of failure. However, after a successful launch has been obtained a great fraction of the overall mission risk is retired.

Aircraft provide regional coverage, can be high resolution, but typically fixed in duration. They can play a major role during intensive observational periods of field campaigns and validation of other measurement types. They fill an important niche between satellites and in situ observations. Overall operating and maintenance costs of aircraft are proving prohibitive to many labs/centers.

Buoys provide point location information as a function of depth, continuous measurements (i.e. high temporal resolution), relatively inexpensive, can be upgraded, can be (re-) calibrated frequently in a lab. Logistics of deployment and vandalism can present challenges. Cruises provide the opportunity for trans-ocean basin transects, interdisciplinary science, information to the ocean bottom, and a platform of opportunity for multiple measurement types. Logistics and daily costs are constraints.

None of these can do it alone – satellites rely on buoys, aircraft, and research cruise measurements for validation; no set of buoys and aircraft can provide global coverage – not all regions are accessible, remote sensing provides context information for point measurements.

Beginning with the U.S. – French TOPEX/Poseidon altimeter mission and continuing with the flight of NASA's NSCATT scatterometer on the Japanese ADEIOS satellite, international cooperation has been critical to satellite oceanography.

3. What role is planned for international cooperation in future satellite oceanography, and is it reasonable for our country to rely on foreign partners to supply oceans observations essential for U.S. operational requirements as well as climate change measurement?

Given the overall costs of satellite missions, international collaboration is very important if not essential. There is certainly a role for international cooperation for satellite oceanography, however greater insight into the sensor characterization and algorithms of international missions is often needed. Highly successful international collaborations include the US/France TOPEX/Poseidon mission and subsequent follow-ons for sea surface topography and the US/Japan the Tropical Rainfall Meaurement Mission. Perhaps the most obvious current and pressing example is the US-French Jason-3 mission to continue the precision altimetry record of sea level rise. Whether the partnership is between NASA or NOAA and CNES or Eumetsat, continuation of the record is a high climate science priority.

In an ideal world there would be multiple (redundant) sources of data to meet operational requirements – this would also benefit climate science. However, we are typically dealing with budgets that do not even consistently support a single source for such data. This is why our nation's present approach is ad hoc and the scientific community has fingers crossed that spacecraft live well past their design lifetime.

In an ideal world, nations would pool resources and plan from the start; in fact, we barely can develop common data formats to share the data after launch. The Global Earth Observing System of Systems (GEOSS) was to facilitate in this regard, but it is far from meeting its potential.

4. Looking forward, what improvements would you like to see in satellite observations of the oceans in order to better understand, predict, and monitor climate change?

First and foremost we need a national strategy for sustained space-based climate observations!

The NRC Decadal Survey for the Earth Sciences recommends the SWOT and XOVWM missions to advance the state-of-the-art in climate-quality ocean measurements. SWOT is a wide-swath altimeter and XOVWM is the next-generation scatterometer. SWOT will extend ocean altimetry measurements closer to the coastline and will for the first time enable measurements of inland water storage in lakes, reservoirs, and wetlands. XOVWM will provide more frequent & improved wind measurements (especially in rainy conditions), higher spatial resolution, and better coverage in coastal regions than previous generations of scatterometers. Together XOVWM and SWOT will improve our understanding of variability in winds and ocean currents. The need for climate quality altimetry and scatterometry is quite clear, yet funding for the 'next' mission is always in peril.

The cost and robustness of the overall climate observing system of satellites and instruments is affected by the number and size of satellites required and the resulting complexity and launch requirements.

5. Are there combinations of instruments or measurements that need to be flown on the same spacecraft so that their observations can be combined into ocean data products?

In many cases there are advantages to flying instruments together. However, few need to be on the same platform in order to achieve these benefits. Advances in formation flying allow sensors on nearby platforms to observe the same scene within moments of each other. This allows a more robust program without adding the complexity of integrating the schedules, budgets, and instruments themselves to the degree required for flying on the same platform. In some cases, however, there is a clear need to fly instruments on the same platform for the sake of either science or efficiency. The SMAP mission, for example, carries a radar and radiometer on the same platform to produce a high quality soil moisture product – they share a platform because they share its 6 meter antenna. In the case of radar altimetry, the radar sensor requires an adjacent passive microwave radiometer to correct for water vapor as the radar signal travels through the atmosphere. Next year we will see the launch of the joint US/Argentina Aquarius mission for sea surface salinity. The salinity retrieval requires the L-Band passive microwave signal to be combined with an adjacent radiometer for an independent measure of sea surface temperature.

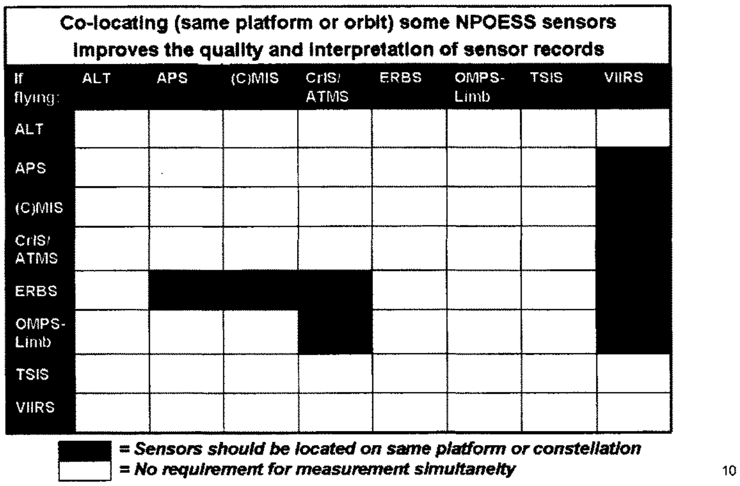
Answers to "Questions for the Record" for Dr. Tom Karl
March 23, 2009

1. **The climate question will confront us for many decades if not centuries to come. Looking forward, what improvements would you like to see in satellite observations of the atmosphere, including precipitation and clouds, in order to better understand, predict, and monitor climate change?**

Through NPP and NPOESS, NOAA will provide sustained key observations to enable improved understanding, prediction, and monitoring of climate change. Improvements include VIIRS, a 22-band sensor which greatly advances capabilities currently provided by AVHRR and the Defense OLS systems, and continues the revolutionary capabilities provided by NASA's MODIS (high spatial resolution globally). NPP CERES will sustain state-of-the-art radiation budget analysis, and OMPS (Limb and Nadir) will provide the high resolution vertical resolution of ozone such that scientists can monitor the replenishment of atmospheric ozone. The CrIMSS sounding system will provide hyperspectral thermal and microwave sounding of the atmosphere and will produce high resolution vertical profiles of atmospheric temperature, pressure and humidity under both cloudy and non-cloudy conditions. The vertical resolution afforded by these systems will far exceed those currently provided by NOAA's HIRS and AMSU systems. In the NPOESS timeframe, TSIS, a state-of-the-art spectral and total solar irradiance monitoring system, will provide sustained detection of complex solar variability that has only recently become appreciated. In all, NOAA is moving into sustained operations of many of the key observational capabilities that were developed and proven in NASA's Earth Observing System (EOS) program.

2. **Are there combinations of instruments or measurements that need to be flown on the same spacecraft so that their data can be combined into products in the way that infrared and microwave sounding data are integrated to produce profiles of atmospheric temperature and moisture?**

To maximize the quality of the data records and the usefulness of the climate information, certain NPOESS climate instruments should exploit sensor co-location per the following figure. NOAA is ensuring appropriate complementary measurements on NPP, NPOESS and Jason flights per the following table. For some of the sensors in the leftmost column of the table, complementary measurements are identified by the colored cells to the right.



3. **What improvements are needed in data systems to strengthen the use of satellite observations in understanding, predicting, and monitoring climate change?**

Data systems must be expanded beyond the current concept of simple data warehouses in order to provide independently understandable and trustworthy climate data records for future generations. To achieve this:

- metadata systems, data about the data, must be significantly enhanced,
- the full provenance, or chain of custody, of the data must be known, open and transparent,
- software to produce the results must be repeatable and subject to independent verification and validation, and
- a subject matter expert must continuously apply scientific stewardship to the data to ensure the data information content is kept up to date and does not lose its value over time.

4. **How would NOAA data systems and centers have to expand or change to support a national climate service mission?**

Every two years NOAA is required by Public Law 102-567, Section 106 to assess its current data management, archival, and distribution capability as well as set forth a data management improvement plan. NOAA has performed this assessment by its four major goals which includes the Climate Goal. The past two *Reports to Congress on Data and Information Management* for 2005 and 2007 can be found at: http://www.ncddc.noaa.gov/environmental-data-management-report-to-congress. The following concepts apply to today's challenges for a National Climate Service:

Expansion and Changes needed in Climate Data Management

Influx of new data: Over the next decade the volume of NOAA's satellite data will increase exponentially from the implementation of new, more sophisticated satellites such as GOES-R and NPOESS. New higher resolution and multi-ensemble simulations of earth system and ocean-atmosphere climate models will generate petabytes. These data will be critical for informed decision-making for climate change adaptation and mitigation policies and practices. Data from higher resolution weather radars will also generate many more petabytes of data. A data management infrastructure such as NOAA's Comprehensive Large Array-data Stewardship System (CLASS) Project is critical to help ensure that these data are accessible in a manner commensurate with user applications. CLASS is currently NOAA's premier on-line source for the storage and distribution of NOAA Polar-orbiting Operational Environmental Satellite (POES) data, NOAA's Geostationary Operational Environmental Satellite (GOES) data, and other derived data. The storage and access capability for CLASS would need to be enhanced for adequate integration of these additional large array data sets as well as other multi-disciplinary data across all of NOAA to help answer climate change related questions.

Climate Computing and Internet Communications Capacity: State-of-the science climate simulations at the scales useful for local and regional climate change adaptation are dependent upon continued investment in super-computer (petaflop scale computing) capacity. Numerous long-term simulations are required to narrow uncertainties to assist aid climate change mitigation policy. Finally, to help steer the further development of a global climate observing systems climate model simulation experiments are required to help ensure that observing systems operate at the most effective space scales for the highest priority essential climate variables.

Data Integration: Continued work will be done to integrate climate measurements across observing systems and climate model output in order to document with a high degree of confidence changes in the state of the climate and their consistency, or lack thereof, with climate model simulations of past and present climate. Most of the existing data management systems were developed to provide data for a particular purpose and access to consistent and integrated data types has hampered past efforts focused on comprehensive understanding. So, while generally efficient for their original purpose, overall many legacy data systems, inherently lead to incompatibilities, inefficiencies, redundancies, duplication of effort, and higher overall costs. An Internet-based Service-Oriented Architecture (SOA) approach is now being adopted by NOAA that will result in improved integration capability to both new and legacy data and

data systems. Standards-based service interfaces are being designed to promote interoperability and allow users seamless access to NOAA Climate data as well as other inter disciplinary data and services from multiple sources, including other agencies. Further information about SOA can be found at:
http://usgeo.gov/docs/Exchanging%20Data%20for%20Societal%20Benefit%20An%20Integrated%20Earth%20Observation%20System%20Web%20Services%20Architecture.pdf

Metadata: Continued work to improve metadata would aid in the development of Climate Data Records. Metadata describes the details about the data. Improved corporate guidelines, standards, and procedures to adequately address metadata requirements are being implemented through the use of International Organization for Standardization (ISO) 19115 standards.

Satellite Acronyms described in Questions 1 and 2

ALT:	Altimeter
APS:	Aerosol Polarimetry Sensor
AMSU:	Advanced Microwave Sounding Unit
ATMS:	Advanced Technology Microwave Sounder
AVHRR:	Advanced Very High Resolution Radiometer
CERES:	Cloud and Earth's Radiant Energy System
CrIMSS:	Cross-track Infrared Microwave Sounder Suite
CRiS:	Cross-track Infrared Sounder
DMSP:	Defense Meteorological Satellite Program
ERBS:	Earth Radiation Budget Sensor
HIRS:	High Resolution Infrared Radiation Sounder
MIS:	Microwave Imager Sounder
MODIS:	Moderate Resolution Imaging Spectroradiometer
NPP:	NPOESS Prepatory Project
NPOESS:	National Polar-orbiting Operational Environmental Satellite System
OLS:	Operational Linescan System
OMPS:	Ozone Mapping and Profiler Suite
SSM/I:	Special Sensor Microwave Imager/Sounder
TSIS:	Total Solar Irradiance Sensor
VIIRS:	Visible/Infrared Imager/Radiometer Suite

THURSDAY, MARCH 19, 2009.

CLIMATE SATELLITE REQUIREMENTS, NASA AND NOAA PROGRAMS

WITNESSES

DR. BERRIEN MOORE, PH.D., CLIMATE CENTRAL

DR. RICHARD ANTHES, PH.D., UNIVERSITY CORPORATION FOR ATMOSPHERIC RESEARCH

OPENING STATEMENT BY CHAIRMAN MOLLOHAN

Mr. MOLLOHAN. The hearing will come to order.

Welcome, gentlemen. Good to see you today.

Dr. Moore and Dr. Anthes, welcome before the Appropriations Subcommittee on Commerce, Justice, Science, and Related Agencies.

Well, we appreciate your coming today to help us understand the requirements for long-term satellite observations to support the understanding, the prediction, and monitoring of climate change and the specific characteristics required of the systems that provide them.

Requirements for precision, accuracy, calibration, and continuity influence costs, but meeting these requirements is critical to getting value from investments in Earth observations.

Both of you have wonderful backgrounds in these areas, and we really appreciate your coming before the Committee this morning to share that with us.

For several budget cycles, this Subcommittee has been wrestling with cost growth, schedule slips, and payload descoping of the NPOESS Program. Traditional wisdom says that one should be able to control two of these three factors, but in this disastrous case, control of all of them has been lost.

To restore essential climate change scope, the just enacted Omnibus appropriation for fiscal year 2009 provides $74 million to restore a clouds and radiation sensor to the NPOESS Preparatory Program and a second copy of this instrument and a complementary solar instrument to the payload of the first NPOESS satellite.

$150 million is provided in the 2009 Omnibus and $400 million in "The American Recovery and Reinvestment Act of 2009" to accelerate development of Earth observation satellites as recommended by the National Research Council, as you well know.

To gain the benefit of flying the suite of climate instruments and satellites, the nation needs effective data systems and centers, numerical models capable of simulating these and other data, and an organizational structure to engage the research data provider and user communities.

Information products must be developed and provided for use on regional to global scales and covering time spans from the seasonal to the multi-decadal.

Dr. Moore and Dr. Anthes, we look forward to gaining your insights as we work to ensure that the nation has a credible climate change research and operational program to complement, guide, and inform the major investments being made in transformative energy technologies, infrastructure, and policy. And continuity, we understand, is very important.

Your written statements, gentlemen, will be made a part of the record. Before I call on you for your oral presentations, I would like to call on our Ranking Minority, Mr. Wolf, for his comments.

Mr. WOLF. Well, thank you, Mr. Chairman. I do not really have any comments.

I am going to digress just for a moment because I see that Dr. Moore is from Princeton, correct?

Mr. MOORE. Not part of the University.

Mr. WOLF. But you live in the Princeton area?

Mr. MOORE. Yes.

Mr. WOLF. I know this is off the subject, but as a scientist, I had a bill in that deals with the whole issue of Lyme Disease and everything else. And I have talked to a lot of people in the Princeton area.

What are your feelings on the whole issue of Lyme Disease? Are you concerned about it when you go out and are——

Mr. MOORE. That is interesting. And this is off——

Mr. WOLF. Yeah. You can just maybe, so we do not take——

Mr. MOORE. What is striking to me was that from my previous post at New Hampshire, I had a small staff of six or seven. Two out of the six or seven had Lyme Disease.

As soon as I moved to Princeton, I went into a hardware store and the very first thing he said to me, he said beware of Lyme Disease.

Mr. WOLF. Yeah. Well, maybe what we can——

Mr. MOORE. And it is a very serious problem, I think, throughout the northeast.

Mr. WOLF. Well, what we might want to do, if I can be in touch with you, I have a bill in with Congressman Smith. We set up an independent analysis to see, but I just thought I would just raise it because when I have been up in the Princeton area——

Mr. MOORE. Very serious.

Mr. WOLF [continuing]. Yeah, the deer fences. In my area, I had a Lyme Disease conference several months ago, and I thought 25 to 50 people, but 300 people came. They all had Lyme, chronic Lyme.

So, anyway, welcome, and I will be chatting with you about that. Thank you.

Thank you, Mr. Chairman.

Mr. MOLLOHAN. You are welcome, Mr. Wolf.

Gentlemen, if you will proceed with your testimony.

Mr. Anthes

Mr. ANTHES. Okay. Sure.

Well, Mr. Chairman and Ranking Member Wolf and members of the Subcommittee, thank you for inviting me to testify on this important subject of NASA/NOAA relations.

It has been said that the Earth is covered two-thirds by water and one-third by Academy reports on NASA/NOAA relations and the transition to research observations.

Mr. MOLLOHAN. I caught that in the last paragraph.

Mr. ANTHES. So I am pleased to add to that one-third and maybe mitigate against sea level rise.

So, anyway, I am Richard Anthes, Rick Anthes, and I am President of the University Corporation for Atmospheric Research. This is a consortium of 73 research institutions and research universities that manages the National Center for Atmospheric Research or NCAR on behalf of the National Science Foundation.

And I want to bring us back to the vision statement in the NRC Earth Sciences Decadal Survey which I co-chaired with my colleague here on my left. And I am not going to read the whole thing, but basically it says that understanding this complex planet and how it supports human life and how humans are affecting its ability to do so in the future is one of the most challenging intellectual problems facing humanity. And it is also one of the most important challenges for us as we seek to, as a society, to achieve prosperity, health, and sustainability.

So addressing these societal challenges, both the intellectual ones and the practical ones of how we coexist with the rest of life on the planet and how we address issues related to sea level change, shifts in storm tracks, and, hence, severe weather, precipitation, droughts, heat waves, water availability, and so on; the key to understanding these, addressing these challenges requires a coherent program of sustained earth observations. And I emphasize coherent and sustained, neither of which we have today.

And then we need the models to make sense of all of these different data from satellites, from ground-based sensors, from aircraft, and so on. We need models to make sense of these observations and to predict into the future not only weather but also climate.

NASA and NOAA are the leading agencies responsible for global observations and prediction models and it is important to make sure that these agencies have well-defined missions and responsibilities and are adequately resourced to meet these essential national needs.

Yet, the present federal agency paradigm with respect to NASA and NOAA is obsolete and nearly dysfunctional. In spite of the best efforts by individuals in NASA and NOAA, and I in no way am critical of the people, the present leadership of NASA and NOAA, the obsolete paradigm has NASA developing and demonstrating new observational techniques and measurements and then transitioning these technologies to NOAA or sometimes DoD for use on a sustained multi-decadal basis.

Well, why is this not working? The traditional focus on research to operations neglects the need for long-term earth observations in favor of emphasis on weather forecasts. And as a weather forecaster from a long time ago, I have nothing against weather forecasts or improving weather forecasts, but it is not sufficient.

The focus only on weather observations leads to the neglect of measurements that have very high climate value but low direct support for weather forecasting. So our ability as a nation to sustain climate observations has been complicated by the fact that neither NASA nor NOAA have the mandate and the required budgets to do so.

So while funding for earth sciences fortunately is improving thanks to the economic stimulus and to the fiscal year 2009 enacted budget and the proposed fiscal year 2010 budget, as far as I can see at the high level, we are still short for what is called for in the Decadal Survey.

And NOAA certainly does not have an adequate budget for sustaining needed weather observations, much less climate observations.

So the first step, the Decadal Survey, which gets a lot of attention on the 17 missions, we had another recommendation in there that as far as I can tell has been neglected.

We recommended that the White House Office of Science and Technology Policy, OSTP, in collaboration with the relevant agencies and in consultation with the scientific community develop and implement a plan, a real plan for achieving and sustaining global earth observations.

And my one take-home message from my oral testimony that I reiterate the importance of this recommendation and urge its implementation in the new Administration.

I thank the members of this Committee for your stewardship of the nation's scientific enterprise for many years, for holding these hearings, and I commend you for supporting the more robust funding for earth sciences in the recent fiscal year 2009 appropriations process.

[Written testimony by Richard A. Anthes, President of the University Corporation for Atmospheric Research follows:]

Testimony by
Richard A. Anthes
President of the University Corporation for Atmospheric Research

Co-Chair, Committee on Earth Science and Applications from Space (2003-2007)
Member, Committee on Earth Sciences, Space Studies Board
National Research Council
The National Academies
and
Past President, American Meteorological Society

Subcommittee on Commerce, Justice, Science, and Related Agencies
Committee on Appropriations, U.S. House of Representatives

March 19, 2009

Mr. Chairman, Ranking Member Wolf, and members of the Subcommittee: Thank you for inviting me to testify on this important subject. My name is Richard Anthes, and I am the President of the University Corporation for Atmospheric Research (UCAR), a consortium of 73 research universities that manages the National Center for Atmospheric Research (NCAR), on behalf of the National Science Foundation, and additional scientific education, training and support programs.

I also served as co-chair of the first ever Earth Sciences *Decadal Survey*,[1] the National Research Council (NRC)'s Committee on Earth Science and Applications from Space: A Community Assessment and Strategy for the Future, which established priorities in Earth observations from space for NASA, NOAA and USGS. In that report we put forth the vision:

Understanding the complex, changing planet on which we live, how it supports life, and how human activities affect its ability to do so in the future is one of the greatest intellectual challenges facing humanity. It is also one of the most important challenges for society as it seeks to achieve prosperity, health, and sustainability.

As detailed in the committee's final report, and by the latest set of reports from the International Panel on Climate Change (IPCC), we are reminded on almost a daily basis that the world faces significant and profound environmental challenges: shortages of clean and accessible freshwater, degradation of terrestrial and aquatic ecosystems, global air pollution, declines in fisheries, devastating floods and droughts, heat waves and wildfires, and above all the accelerating pace of substantial changes in climate. These changes and stresses are not isolated; they interact with each other and with natural variability in complex manners that affect local, regional, and global scales in unpredictable ways. Addressing these societal challenges requires that we confront key scientific questions related to ice sheets and sea level change; large-scale and persistent shifts in storm tracks and hence precipitation, droughts, and water availability; transcontinental air pollution; and impacts of climate change on ecosystems, human health, and occurrences of extreme weather events such as hurricanes.

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[1] A free download of this report is available at: http://www.nap.edu/catalog.php?record_id=11820.

Yet at a time when the need for observations and information about our planet has never been greater, we are faced with an Earth observation program that is in trouble and will dramatically diminish in capability over the next 10-15 years.

As requested, I will summarize my views regarding current interagency collaboration between NASA and NOAA and its impact on our nation's ability to monitor and respond to global climate change in the future. NASA and NOAA are the leading agencies responsible for global observations and prediction models based on these observations, and it is important to make these agencies healthy and their collaborations as strong as possible.

LONG-TERM SUSTAINABLE EARTH OBSERVATION SYSTEM

There is a crisis not only with respect to climate change and the associated changes in weather patterns, which really matter to people, but also the absence of a coherent, coordinated Federal environmental policy to address the challenges. In the nearest term possible, aging space- and ground-based environmental sensors must be replaced with technologically improved instruments. Beyond replacing aging instruments, there is a need to enhance continuity in the observations, so that policy makers, informed by science, will have the necessary tools to detect trends in important Earth indicators and craft wise and effective long-term policies. However, continuity, or *sustained* long-term observations, is not an explicitly stated requirement for either the "operational" or "research" space systems that are typically associated with NASA and NOAA programs, respectively.

Overall, Earth science and many applications depend on long-term, sustained measurement records garnered from an Earth satellite observation system that is efficient, economical, and predictable. This concept has been reinforced by numerous NRC panels and most recently by the decadal survey report which stated, "NASA should develop a science strategy for obtaining long-term, continuous, stable observations of the Earth system that are distinct from observations to meet requirements by NOAA in support of numerical weather prediction."

Moreover, long time series are required to advance Earth system science. Assured data streams are also required to encourage private sector investment in application-oriented products and services that provide direct societal benefits. The system must be robust and sustained to ensure accurate and timely products for operational predictions and other valuable applications.

CURRENT ISSUES IN THE NOAA/NASA RELATIONSHIP

The present federal agency paradigm with respect to NASA and NOAA is obsolete and nearly dysfunctional, in spite of best efforts by both agencies. This paradigm currently has NASA developing and demonstrating new observational techniques and measurements deemed useful for prediction or other applications. These are then transitioned to NOAA (or sometimes DoD) and used on a sustained, multi-decadal basis. However, this paradigm is not working for a number of reasons. The two agencies have responsibilities that are in many cases mismatched with their authorities and resources: institutional mandates are inconsistent with agency charters; budgets are not well matched to the needs; agency responsibilities are not clearly defined, and shared responsibilities are supported inconsistently by ad hoc mechanisms for cooperation.

The traditional focus on "research to operations," which has been the subject of many NRC studies, often neglects the need for long-term, consistently processed time series of Earth observations in favor of emphasis on weather forecasts. While weather forecasts are critically important, this focus may lead to the neglect of measurements that have high climate value but low direct support for weather forecasting. In the past, NASA has occasionally flown multiple research missions to generate long, continuous data records which NOAA uses to improve "operational" forecast products and services. In addition, NASA and NOAA, working together, have invested in instrument development and implementation. However, these efforts have been ad hoc at best and not sustained over a long period of time.

While NASA and NOAA collaborate effectively at some very important operational and administrative levels, NASA's role, as both a research and development agency and a leader in Earth system observations from space, is only consistent and sustainable if there are clear, efficient mechanisms for ensuring the continued acquisition of selected environmental measurements whose need and value have been demonstrated. Theoretically this responsibility could be turned over to NOAA, but NOAA's budget and capabilities are totally inadequate to assume new satellite responsibilities. NOAA's responsibilities for civil weather forecasts and warnings, along with its desires to lead the nation's climate services, are inconsistent with its demonstrated inability to garner resources to ensure a robust satellite constellation, even for legacy short-term prediction measurements, let alone the ability to expand the system to include new and sustained climate observations.

OVERALL STRATEGY NEEDED TO STRENGTHEN NASA AND NOAA

The required system of Earth observations from space requires missions to extend and build off one another. In many instances, it is desirable for each mission to overlap slightly with other missions providing the same observations to give us a continuous record for establishing trends, for calibration and intercomparison of different instrument and processing systems, and ultimately to supply the necessary information for responding on both a regional and local policy level. While increased funding for Earth science, as approved in the economic stimulus legislation is welcomed, as are increases in the FY09 and FY10 budgets, they are insufficient to close the gap between what is needed and what may become available to meet the decadal survey recommendations. And new observations are not the only observations needed – we also must ensure continued operations for existing aging satellites. In addition, it is critical that we support the necessary infrastructure, particularly supercomputers, to process and use the observations to produce better and more relevant forecasts and other information products. It will also be essential to develop a long-term strategy to plan for and incorporate new missions.

Our ability as a nation to sustain climate observations has been complicated by the fact that no single agency has both the mandate and requisite budget for providing ongoing climate observations, prediction, and services. While interagency collaborations are sometimes valuable, a robust, effective program of Earth observations from space requires specific responsibilities to be clearly assigned to each agency and adequate resources provided to meet these responsibilities.

As a first step, the decadal survey specifically recommended that the White House Office of Science and Technology Policy (OSTP), in collaboration with the relevant agencies and in consultation with the scientific community, should develop and implement a plan for achieving and sustaining global Earth observations. This plan should recognize the complexity of differing agency roles, responsibilities, and capabilities as well as the lessons from implementation of the Landsat, EOS, NPOESS, and GOES programs. I reiterate the importance of this recommendation and urge its implementation in the new administration.

ADEQUATE BUDGETS

I recognize that this Committee, like the country, is faced with difficult decisions. In a time in which missions being developed by NASA and NOAA are frequently over budget (sometimes due to an expansion in scope), additional resources for this type of strategy are hard to find. With that in mind I commend this Committee for supporting the more robust funding levels in the recent FY 2009 appropriations process. However, while funding in Earth science is improving, we are still well short of what is called for in the Decadal Survey. An examination of current budget projections and the increasing scope and costs of the Tier 1 decadal survey missions (SMAP and ICESat-II) makes it clear that the first phase of decadal survey missions cannot be completed before 2016-2017.

CONCLUDING REMARKS

I note that the NRC is about to start a study titled "Assessment of Impediments to Interagency Cooperation on Space and Earth Science Missions" that will address these issues once again. The study will assess impediments, including mission cost growth, to the successful conduct of interagency cooperation on space science missions and recommend steps to help facilitate successful interagency collaborations on space science missions. However, we should not wait for this study, which follows many similar studies over the past decade. It is simply time to move forward with implementing the consistent set of recommendations from these previous studies.

I sincerely thank the members of the Committee for your stewardship of the nation's scientific enterprise and your understanding that the future strength of the nation depends on the investments we make in science and technology today.

Mr. MOLLOHAN. Thank you, Doctor.

Dr. Moore.

Mr. MOORE. Mr. Chairman, Ranking Minority Member Mr. Wolf, other members of the Committee, thank you for inviting me here to testify today.

My name is Berrien Moore, III, and I am Executive Director of a new nonprofit in Princeton. It is a sporting time to leave a University and go to a new nonprofit in this economy.

I appear here, however, as Chair of the Committee of Earth Studies of the Space Studies Board of the National Academy. I endorse what my colleague, Dr. Anthes, had said about the Decadal and about the recommendation calling for the plan. And I would like just to speak informally about my written testimony.

First of all, regarding the budget, we have been very appreciative, the scientific community, for the near-term budget actions, but satellites are developed over a five or six year period. And what I have seen is that there has never been an adequate out-year budget that would really allow one to implement the recommendations in the Decadal Survey.

And I do not know what the out-year budget for 2010 is for earth science, but I have read about what the NASA out-year budget is for NASA and I am worried.

The second thing in addition to the resources in the out-years, there is this question of controlling costs. I think we have got to find a way to control costs better. I am not certain what those techniques are and how we might do it, but I do know it is a serious problem.

I have some thoughts about that that we can talk about later. Now, let me deal with the question of climate and the nature of the climate problem.

First of all, it is a very serious societal issue. Let me just mention two or three things.

Carbon dioxide emissions are up 40 percent from 1992. Nineteen ninety-two is the year of Kyoto. So rather than winding back emissions to 1990 levels as suggested in Kyoto, we are up 40 percent.

Secondly, sea level rise is increasing twice as fast as expected. Summertime Arctic Sea ice is decreasing far faster than any model had predicted.

That brings me to the issue of how do we approach this problem of climate. We fundamentally have to approach the issue of climate, which is a long-term issue, with very sophisticated computer models. And they involve, as Rick Anthes just mentioned, more parts of the earth's system than just weather forecasting.

A weather forecasting model really only needs sea surface temperature. It does not need to know anything about ocean circulation to forecast tomorrow's weather. But as you start looking out 10, 20, and 30 years, more parts of the earth's system come into play.

Now, this poses a very real problem. How do we validate a projection out 30 years? With weather models, we validate it every day and if we do not like the model or the modeler, we can fire them. But how do we do this with climate models?

And there is a very interesting technique that is emerging. We take various modes of climate. The most popular, the most well known is El Niño or La Niña. These are the two climate modes that start in the western Pacific Ocean and they actually ripple all the way around the planet. But how well do our climate models predict El Niño and the patterns of El Niño?

Now, with this, you do not want to just talk about what happens in the western Pacific. You want to see how well do the climate models catch all of the dynamics of an El Niño condition. We know that it affects rainfall over Brazil. It affects air mass transports over Indonesia. It affects sea surface temperatures off of Africa. It affects California weather.

How well do we catch the whole system? Well, in order to know what the whole system is doing, we have to have earth observations of sea surface winds, of precipitation, of vegetation cover, the things that would be affected by El Niño.

Well, you do not just have to worry about El Niño. There are other patterns. There is something called the North Atlantic oscillation and this is something that has a ten year periodicity. It changes every ten years.

So we can go back to the last 20 years of climate records, satellite observations, and see how well did we capture the North Atlantic oscillation. And this then becomes a fundamental test for our models in the way in which we look to the future.

Let me just conclude with one set of observations that I think are particularly relevant given the recent failure of the orbiting carbon observatory to make orbit. This is something that I know quite well.

In fact, in 2000 and 2001 when I was at the University of New Hampshire, I competed against the orbiting carbon observatory. I suggested an alternative way of doing it using lasers. The orbiting carbon observatory was going to use reflected sunlight off of the planet to determine how much CO_2 there is in the atmosphere.

The value of that determination is one could actually work backwards. You look at how much CO_2 there is in the atmosphere. You look very carefully around the planet. And there are slight differences. The biggest difference is there is more CO_2 in the northern hemisphere than there is in the southern hemisphere. Why? There is more industrial activity in the northern hemisphere.

Well, it turns out there are east/west differences also. And if you look very carefully, you can work backwards to where is the CO_2 coming from and where is it going to. The orbiting carbon observatory was to make those observations. Unfortunately, it did not make orbit.

So what do we do in the future? Well, one thing we know for sure we are going to be measuring greenhouse gases and gases like CO_2 from now on, at least for the next 100 years. Therefore, we best get on with it because we absolutely must understand where is carbon dioxide coming from, where is it going to.

The other that I would like to mention because you raised it, Mr. Mollohan, it is very fortunate that we are going to fly the CERES, the C-E-R-E-S, this is the cloud and radiation instrument, and the total solar radiance measurement.

Why? Well, the solar radiance measures go look at how much energy is coming from the sun. So that is what is coming into the system. The CERES instrument looks at the planet and determines how much of that solar energy is reflected off the top of the atmosphere, how much enters the atmosphere, and then how much later comes out not as solar energy but as heat. That is the energy budget.

And greenhouse gases like what I just mentioned with CO_2, what the greenhouse gases do is they change that equation ever so slightly. So with the total solar radiance and the CERES instruments, we are beginning to monitor the earth's radiation budget which is the fundamental thing.

My testimony mentions also what the Decadal Survey laid out for more detailed measurements of that budget, but I will conclude here and simply say that we face some very real issues with this question of climate. It is a serious and legitimate scientific problem and it is an important societal issue. We do not have the observational capability to adequately address this problem.

Thank you very much.

[Written statement by Berrien Moore III, Ph.D. Executive Director climate central Princeton, New Jersey follows:]

Statement of

Berrien Moore III, Ph.D.
Executive Director
Climate Central
Princeton, New Jersey

And

Chair
Earth Studies Committee
Space Studies Board
National Research Council
The National Academies

before the

Commerce, Justice, Science Subcommittee
House Appropriations Committee
The U.S. House of Representatives

19 March 2009

Mr. Chairman, Ranking Minority Member, and members of the committee: thank you for inviting me here to testify today. My name is Berrien Moore III, and I am the Executive Director of Climate Central in Princeton, New Jersey and Director Emeriti of the Institute for the Study of Earth, Oceans, and Space at the University of New Hampshire. I appear today as Chair of the Earth Studies Committee of the National Research Council's (NRC's) Space Studies Board. In addition, my colleague Dr. Anthes and I served as co-chairs of the NRC's Committee on Earth Science and Applications from Space, which completed the Decadal Survey in 2007.

As you know, the NRC is the unit of the National Academies that is responsible for organizing independent advisory studies for the federal government on science and technology. The NRC has been conducting decadal strategy surveys in astronomy for four decades, but this was the first decadal survey in Earth science and applications from space.

Before addressing the role of space-based observations for improving our understanding of the planet's climate, I must express my concern about realizing the recommended missions from the Decadal Study.

For the moment, I will focus upon NASA. The Decadal Study concluded that the recommended NASA program could be accomplished by restoring the Earth science budget in real terms to the levels of the late 1990s. What I have observed since 2007 is that even with the political momentum following the Study and even with modest near-term increases, there has never been an "out-year" commitment to actually accomplish the recommended program. In fact, it is worse than that; it does not appear that there is an adequate commitment of funds to accomplish even a third of the program by 2017. This lack of "out-year" commitment that has characterized the last two budgets may be different in the future. I hope so; it should be so, but when I read about the out-year funding for NASA as a whole, I fear that the future for these key measurements is not good.

Finally, compounding the inadequate funding is the cost growth of the missions currently in development as well as the early missions from the Decadal Study. We must find a better way to manage costs.

Let me turn to climate change.

The issue of Climate Change poses a *serious* societal problem: First, the consequences could well be dire if the major industrialized nations do not act aggressively to alter their use of fossil energy, and second, the changes in our energy systems that are needed are without historical precedent.

The issue of Climate Changes also poses an almost uniquely *difficult* scientific problem. The difficulties come essentially from two sources.

First, the climate system is exceptionally complex. The range of important time constants is broad: from years to decades to centuries and hence almost all parts of the Earth system become involved in understanding the future evolution of the planet's climate.

Second, scientists often like to have a control group—those that get the medicine and those that do not; comparisons can then be made to evaluate how well the predicted effectiveness compared to what is to be measured. With regards to the increase in greenhouse gases and the changes in the planet, we have no other planet on which to carry out the control study—we cannot compare the Earth's with and without the increase in greenhouse gases.

In such a situation, we are fundamentally dependent upon our ability to develop models built upon our understanding of the dynamics of the planet's atmosphere, biosphere, hydrosphere, cryosphere and how these subsystems interact in the overall Earth system.

Over the last several decades and aided by ever more powerful computers and an array of space-based and *in situ* observation, we have made remarkable progress in modeling the climate system.

It seems to me, that two fundamental questions must be answered:

1. Given a suite of energy futures, what are the expected climate changes?
2. How confident are we in our answer?

The first question sets the pace required to avoid unwelcomed or dangerous changes in climate. Given the centrality of fossil fuels in all economies, we need to get the pace of change right with some margin on the safe side. The question of how much margin is needed is governed, in part, by our ability to answer the second question.

Hence for better or worse, our very best tool for evaluating the risk of climate change are climate models such as those developed by NOAA's Geophysical Fluid Dynamics Laboratory, the National Center for Atmospheric Research, and within the Department of Energy's Lawrence Livermore National Laboratory.

Given the complexity of the climate system, we must have means of testing our understanding as expressed through these highly complex mathematical models. There need to be ways to evaluate the prognostic skill of any model and of understanding the characteristics of this skill. In the case of weather prediction, one can test the skill—we do this daily. One can even question the skill and perhaps fire the forecaster. But for climate the problem is fundamentally different. The question of predictability of climate is integral to understanding the physics behind the low frequency natural variability of climate and distinguishing the signal of climate change. In other words, there are the paired challenges of capturing "natural" variability of climate as well as detecting (and predicting) the emerging human-forced climate signal. This dual challenge is distinctively climatic in nature; as is the *longer-term* character of climate projections; these linked aspects of the climate problem and system are unavoidable and problematic.

Fortunately, there appear to be coherent modes of behavior (such as El Niño-Southern Oscillation, Pacific Decadal Oscillation, and North Atlantic Oscillation) that not only support a sense of optimism in attacking the prediction problem, but that also may offer measurable prediction targets that can be used as benchmarks for evaluating our understanding of the climate system. Moreover, predicting these modes represents a valuable contribution in itself.

Such demonstrations and the insights gained in developing and making prognostic statements on climate modes frame an important area for further work. This success also clearly demonstrated the importance of space-based observations such as the Topex-Poisidon and Jason ocean topography data, sea surface winds from QuickScat and WindSat, and MODIS Sea Surface Temperature data. My concern about this set of measurements is that sea surface winds is not adequately addressed. The Decadal Study recommended flight by NOAA of a sea surface winds instrument. I am worried that budget challenges for NOAA are having a negative impact on realizing an ocean winds instrument. One path forward would be to proceed with a simpler instrument; namely fly a copy of QuickScat—we need to avoid having the perfect be the enemy of the good.

The success in El Niño forecasting and in unraveling the large-scale climate modes is first order. And yet, the range of uncertainty in climate forecasting remains a large problem.

Much of the uncertainty about climate change and the degree of warming centers on clouds.

It is generally accepted that the net effect of clouds on the radiative balance of the planet is currently negative and has an average magnitude of about 10-20 Wm^{-2}; in other words clouds have a cooling effect overall.

The effect of clouds on the radiative balance consists of a short-wave cooling (the albedo (reflectivity) effect) of about 40-50 Wm^{-2} and a long-wave warming of about 30 Wm^{-2}. Unfortunately, the size of the uncertainties in this budget is large when compared to the expected anthropogenic greenhouse forcing. Understanding the cloud-climate connection is a particularly challenging scientific problem because it involves processes covering a very wide range of space and time scales.

There are, however, hopeful signs.

The CloudSat and Calipso missions (launched in 2006), which fly in formation (in the A-Train) with the NASA Aqua Mission, are providing valuable profiles of cloud water content, optical depth, cloud type, and aerosol properties, and this information leads to understanding processes.

From an energy budget view point, there is also good news. The Clouds and the Earth's Radiant Energy System (CERES) that is flying on the NASA Terra spacecraft are providing new insights on clouds and the heat balance of the planet. The added good news is that it will now be flown on the NPOESS Preparatory Mission and on the first NPOESS spacecraft. Th e Total Solar Irradiance Sensor (TSIS), which provides detailed measurements of the energy from the sun, will fly on NASA's Glory mission and again on the first NPOESS spacecraft.

Given that it is likely that the concentration of greenhouses gases will continue to increase in the atmosphere for *at least* the next 30 years, and that this change will force a change in the Earth energy balance, then we must monitor that energy balance and the solar output, if we are going to be able to make credible climate statements including forecasts. Even if there were an extraordinary change and greenhouse gases were stabilized, there would still need to monitor the Earth's energy budget because of the pre-committed warming. This is the reason that the Decadal Study recommended the Climate Absolute Radiance and Refractory Observatory Mission (CLARREO), which will build upon the record of CERES and other Earth radiation budget measurements. It seems obvious to me that we will need to monitor this basic energy budget for the planet from now on.

One central reason is that while current evidence that the current effect of clouds is cooling (negative feedback), the nature of the *future* cloud feedback is not clear. Will it remain *negative*?

If the planet warms, then it is likely that evaporation will increase which probably implies that cloud water content will increase but the volume of clouds and the area they cover may not. What will be the effect and how will the effects be distributed in time and space? What will be the effect of changes in the distributions of aerosols? What is the effect of changes in the chemistry of the atmosphere? *We simply must understand the underlying processes and this requires observations.*

The cloud feedback problem is important since it affects the albedo (roughly the reflectivity) of the planet. There is another issue associated with the planet's albedo.

There is increasing evidence that there is a rapid (more rapid than any model predicted) decline in extent and thickness of Arctic sea ice in the summer. This decline appears to be connected with the observed recent Arctic warming. It is not known whether these changes reflect anthropogenic warming transmitted either from the atmosphere or the ocean or whether they mostly reflect a major mode of multi-decadal natural variability. Some of this pattern of warming has been attributed to recent trends in the Arctic Oscillation; however, how the anthropogenic signal is imprinted on the natural patterns of climate variability remains a central question.

What does seem clear is that the changes in Arctic sea ice are significant, and there is a positive feedback that could be triggered by declines in sea ice extent through changes in the planetary albedo. If the Arctic shifted from being a bright summer object to a less bright summer object—an open Arctic sea, then this would be an important positive feedback on a warming pattern. The shift could be rapid and dramatic.

There is another feedback loop through increased evaporation lending to increases in cloud formation and enhanced albedo. Which will win? Are we to have an open Arctic sea in summer? The issue and the uncertainty are disturbing. Knowledge of the planet's energy budget is fundamental as is knowledge of its cryosphere.

IceSAT, MODIS, GRACE, and radar data from international partners have provided important observations, but the problem of changes in the snow and ice cover of the planet are immense and the system is inadequately monitored and understood. This is one reason that ICESAT-II was recommended in the first tier of Decadal missions

In thinking about climate change, we may be paying too much attention to temperature—the term global warming may actually focus concentration on too restrictive a topic. After all, most people on the planet live in areas far warmer than New Hampshire. It may well be that changes in the water cycle (rainfall, soil moisture, river flow, and evaporation) are more significant—particularly when these changes are viewed against the backdrop of other changes including population growth.

I state the obvious: precipitation is absolutely key for human society. It is obviously tied up with the cloud feedback problem via atmospheric water vapor, temperature, and other state variables and processes in the climate system. In other words, this is an area where our ability to probe possible changes in the patterns of precipitation is far weaker than our ability to bracket patterns of temperature change.

Patterns of precipitation set the stage for, and are partially determined by, evapotranspiration and the resulting distribution of soil moisture. Soil moisture is an important determinant of ecosystem structure and hence a principal means by which climate regulates (and is partially regulated by) ecosystem distribution. It is also central for agriculture. Our inability to bracket adequately changes in precipitation translates into a similar weakness in handling soil moisture, and soil moisture is dead central for terrestrial ecosystems and agriculture.

Returning to precipitation, the Tropical Rainfall Monitoring Mission has contributed significantly to our understanding of this central feature of our planet—for this we can be thankful. Unfortunately, the news is not always good—the Global Precipitation Mission continues to suffer cost growth and delay, and I am worried that the Soil Moisture Active and Passive (SMAP) mission faces a similar fate.

I would like to close with some thoughts about CO_2 and climate and human behavior.

The carbon dioxide problem is a big problem. The Ozone Hole was a big problem and not easily addressed even though CFCs were not in the center of the global economy. Fossil fuels are in the center of the global economy. Furthermore, the CO_2-Climate interaction has a very challenging dynamic.

Three Facts must be stressed:

1. To stabilize the concentration of carbon dioxide in the atmosphere, we must drastically reduce (cut by more than 80%) the global consumption of fossil fuels as well as manage the biosphere far better. In other words, stabilizing the atmospheric concentration of CO_2 requires far more than simply stabilizing emissions—if we could wave a magic wand and instantly stabilize CO_2 emissions today, the atmospheric concentration would continue to increase almost indefinitely with stable emissions.
2. To stabilize the global mean temperature below levels of harm *requires* that we acknowledge that global temperature increases lag the increases in the atmospheric concentration of carbon dioxide. Consequently temperature continues to increase globally well after the stabilization (in the atmosphere) of human induced greenhouse gases (e.g., principally carbon dioxide).
3. Finally, we are far from stabilizing the emissions of CO_2. More than 15 years have elapsed since the Climate Convention in 1992, and in the mean time, global CO_2 emissions from fossil fuels have increased by roughly 40%. The current trend in the CO_2 concentration in the atmosphere is above any of the IPCC Scenarios that were devised to explore future climates. We need to alter course.

I also think that we need to understand better the Carbon Cycle—where is CO_2 coming from; how much and where is it taken up by terrestrial biota; what is being released (net) by vegetation and through landuse, and how much and where is it absorbed into the oceans. How do these patters of sources and sinks vary with climate and weather patterns?

Understanding and perhaps managing carbon sinks (and other carbon sources) will be important as will having independent knowledge of fossil fuels sources.

Direct oceanic and terrestrial measurements of carbon and/or the flux of carbon dioxide are resource-intensive and hence sparse, and difficult to extrapolate in space and time. The problem of source-sink determination of CO_2 will be aided greatly by such surface measurements and studies, but it will not be resolved by this approach.

There is, however, a different complementary approach, and this is what the Orbiting Carbon Observatory (OCO) was to pursue. The geographical distribution of CO_2 in the atmosphere and its temporal evolution can be used to quantify surface fluxes. In other words, by measuring carefully the differences in CO_2 concentrations in the atmosphere, one can "work backwards" to the terrestrial and oceanic sources and sinks of CO_2.

Unfortunately, there was a launch failure and OCO did not achieve orbit.

Fortunately, the Japanese Greenhouse gases Observing Satellite is on orbit and other instruments (NASA's Atmospheric Infrared Sounder (AIRS) and the European Infrared Atmospheric Sounding Interferometer (IASI)) can help. Also, the Decadal Study has recommended an active laser-based mission, ASCENDS, to produce a highly precise global dataset for atmospheric CO_2 column measurements without seasonal, latitudinal, or diurnal bias.

The coupling of this high-precision, high-volume datastream with atmospheric inversion, data assimilation, and coupled atmospheric, terrestrial and ocean carbon modeling will enable us to quantify the sources and sinks at unprecedented space and time resolution. The final scientific outcome will be both greatly advanced understanding of the global carbon cycle as well as the essential scientific foundation for making reasoned future projections of atmospheric concentrations of carbon dioxide.

In sum, we are in need of knowledge of the Earth. We know that the planet's environment is changing on all spatial scales including global, and change is rapid, likely more rapid than at any time in human history. Many of these changes are occurring because of human activity. These human-induced changes are over and above the stresses imposed by the natural variability of a dynamic planet.

The changes cascade through the Earth's environment in ways that are difficult to understand and often impossible to predict. At the least, these human-driven changes in the global environment will require that societies develop a multitude of creative responses including strategies for mitigation and adaptation. The linked challenges of confronting and coping with global environmental changes and addressing and securing a sustainable future is daunting and immediate, but they are not insurmountable. The challenges can be met, but only with a new and even more vigorous approach to observe and understanding our changing planet.

Mr. MOLLOHAN. Thank you, Dr. Moore.

Thank you both.

Let me pick up with both of you and either of you can answer. Well, Dr. Moore, since you ended your testimony with this, why don't you just pick up the first answer.

This whole week, we have had excellent testimony, and if we were not impressed before the hearings started at the beginning of the week, we certainly are now about the seriousness of the phenomena of global warming and the drivers, particularly CO_2 emissions from human activity, which impressed upon us the importance of the Orbiting Carbon Observatory.

So I would like you to talk a little bit about that—more why it was so important and the gap it bridged and what we are relying upon now and what we can substitute or how we respond to the failure of the launch and then when we are looking forward, what do we rely upon in the future.

Mr. MOORE. All right. First of all, I want to be very clear that I did as I said. I competed against it and so I had in some sense an interest in this topic.

As I mentioned, what the Orbiting Carbon Observatory was going to do is to measure very precisely the differences in CO_2 concentration around the planet. And those differences directly reflect where CO_2 is coming from and where is it going to. We know that a lot of CO_2 is absorbed by the oceans. Some goes back into regrowing forests.

You cannot make that measurement what scientists call in situ. There is no way you can go out and adequately measure CO_2 exchange at the surface of the ocean. It is impossible.

Mr. MOLLOHAN. And I do not want to interrupt you, but I want to be interactive with you on this. So we are talking about CO_2 from any source?

Mr. MOORE. Right.

Mr. MOLLOHAN. So you would have identified it coming from stationary sources, you would identify it coming from mobile sources, and the OCO would identify not only the source but its distribution after it emanates from the source? Is that——

Mr. MOORE. Yes. But I think most importantly, it would at fairly large regional scales say how much CO_2 is coming off of that region and how much is going back into that region. And you really get the net and you get that, I think, with OCO probably would have been able to get maybe monthly means, maybe weekly, but I think probably monthly at a regional scale.

The finer you can make that measurement and the more densely you can make that measurement, the better you are at being able to get back to finer spatial scales and finer temporal scales.

I mentioned that OCO worked off of reflected sunlight. Essentially it almost measures the greenhouse effect. That is, it looks at how much sunlight comes in and some of that sunlight is absorbed by CO_2. And then as the sunlight is reflected back off the planet, it measures that. And it essentially can measure by the fact that CO_2 absorbs energy how much CO_2 there is in the atmosphere, but it requires sunlight.

So that means it makes no nighttime measurements and it makes no measurements in the high latitudes like over Moscow in the wintertime because there is just simply not enough sunlight. It makes no measurements over very cloudy conditions because you are not sure about where is the sunlight coming from. It is bouncing off of clouds.

But it was going to make a real contribution. I think to go forward, we would probably go forward with an active instrument which was not really ready. That is what I suggested in 2000, but I probably was overreaching.

But by now in 2009, I think it would be logical to take the next step in which case now you take a laser and you shine the laser down, not damaging anything, on the wavelength that CO_2 absorbs energy. So in some sense, you take the sun with you. And that way, you would make measurements day, night. You make them over the high latitudes in the wintertime. You make them off the tops of clouds. You make them between the clouds. But we have to get on with that.

The Decadal Survey recommended a mission. It is called ASCENDS. I will not bother you with the acronym. It is just easier to remember ASCENDS. And that is the second tier of missions. And this takes me right back. We are not even on a path to implement a third of the Decadal Survey because of this lack of out-year monies. And, therefore, ASCENDS is not in that first third.

Mr. MOLLOHAN. It is in the second third; is it not, Dr. Anthes?

Mr. ANTHES. Well, let me first say why these high resolution global measurements of CO_2 are useful from my point of view.

You have all seen the Mauna Loa record.

Mr. MOLLOHAN. The what? I am sorry.

Mr. ANTHES. The Mauna Loa record in Hawaii that shows the Keeling curves as one of the most fundamental benchmark observations we have ever taken. And it shows how the carbon dioxide has been going up gradually, up and down with the seasons, up and down, but there is a clear upward trend. The ups and downs are because Mauna Loa is in the northern hemisphere.

And so in the summer, when all the plants are taking up CO_2, the actual CO_2 goes down in the northern hemisphere, but then it goes up in the next winter when the plant activity is not as active. And then it goes down again the following summer. So you can see ups and downs seasonaly, but the trend is unmistakably going up. Nobody, not even the most skeptical global change, global warming person, denies this Mauna Loa record.

But the Mauna Log record is a global measurement and it is way up in the atmosphere. It is an average. It does not look at where the CO_2 being emitted over China is, where the CO_2 emitted over the U.S. is, the southern hemisphere.

So we need these observations on the regional basis and every day so that, number one, we can verify models, verify, check our models, make sure our models of the carbon cycle are working correctly because if they are not showing higher CO_2 concentrations over China, for example, or the East Coast of the U.S., then there is something wrong with the models.

We also need it, too, for checking the effectiveness of policies. If we try to limit CO_2 emissions somehow, we need to know whether these policies we enact are being effective.

And so these are two reasons why we need this spatial distribution and temporal resolution, to check our understanding of the carbon cycling models and to verify treaties, if you will, to know where the major emissions are. So that is why we need them.

Now, the orbiting carbon observatory had a lot of positive things. Number one, it should have been up there right now. ASCENDS is going to be, even under the best scenario, eight, ten, twelve years in the future. So there is going to be a huge gap in this needed capability.

ASCENDS and OCO are different technologies. As Berrien mentioned, OCO is passive. You do not need an active laser. So, therefore, it is cheaper and perhaps more useful for long-term, monitoring.

However, OCO does not observe anything during the night. And the active technology does get observations during the night. So we are always faced with these tradeoffs. The different technologies have advantages in some areas and disadvantages in others.

I understand that NASA is looking at the pros and cons of redoing OCO, relaunching an OCO. I think that process is very good and I support it. They will be looking at the pluses and minuses of, doing another OCO versus, say, looking at other satellite systems that are up there now or moving ASCENDS up in the queue.

I think that is a good process and you need objective experts looking at the pros and cons of these things.

Mr. MOLLOHAN. What about relying on foreign instruments?

Mr. ANTHES. Well, if the foreign instruments can do the job, that would be okay, but let me say how would you like to rely on foreign governments to defend the U.S.?

Mr. MOLLOHAN. How would you like to rely on foreign governments to get your humans into space?

Mr. ANTHES. Exactly. So, you know, I think that the U.S. needs some capabilities——

Mr. MOLLOHAN. We have done it before.

COOPERATE AND COLLABORATE WITH OTHER NATIONS

Mr. ANTHES. I know, so I think this brings up a really good question about how much we cooperate and collaborate with other nations. We need to do as much as we can and we do. We have many good collaborations with the European Space Agency, Brazil, Japan, even countries which are not that closely——

Mr. MOLLOHAN. But your point is we should do it?

Mr. ANTHES. We have got to have a minimal——

Mr. MOLLOHAN. It is so important that we should do it?

Mr. ANTHES. We have got to have a minimal capability. You would not rely on another country for weather forecasts.

Mr. MOLLOHAN. Right.

Mr. ANTHES. And we should not rely on them for climate forecasts. We have to have your own, at a minimal level, at least at a sustaining level, and then rely on the other observations of other countries to fill in the gaps. But we have to have a bare-bones capability on our own in my opinion.

Mr. MOLLOHAN. Okay. Bottom line question, what do you recommend——

Mr. ANTHES. I have been waiting for——

Mr. MOLLOHAN [continuing]. If you have a specific recommendation?

Mr. ANTHES. I would recommend waiting for the NASA full evaluation.

Mr. MOLLOHAN. Okay.

Mr. ANTHES. I think there are pros and cons and I hesitate to be——

Mr. MOLLOHAN. Fair enough. Thank you.

Mr. Wolf.

NEW NASA ADMINISTRATOR

Mr. WOLF. Thank you, Mr. Chairman.

Just to follow-up, when will that be? There is no NASA Administrator. There is no NASA Administrator on the scene. The gentleman who was speculated to be, there is now speculation that he will be the special envoy for Darfur. So he went from NASA to Darfur in about two months.

And so when? Who is doing this? Who has the responsibility? Will they act before there is a new Administrator? When is the expectation that this will be decided?

Mr. ANTHES. Well, the study is underway right now being led by the Earth Sciences Director at NASA, the study for whether to do OCO or not. Who makes that decision, I suppose there is an acting Administrator.

I think a NASA Administrator is needed as soon as possible, if that is your question. But I think the studies are going on and hopefully when the study is done, we will have a NASA Administrator. But I take your point. We need a good NASA Administrator.

Mr. MOORE. In that regard, I think the technical issue—I certainly support what Rick Anthes said about having—let this process going forward, evaluating the pros and cons, but if the decision is to refly OCO or if the decision is to advance the active mission, there is going to need to be—that has a financial implication. And I do not believe that there is adequate funds in the current budget to execute either of those decisions.

And in that sense, Mr. Wolf, I concur that the technical issue could be evaluated at the scientific level, but there is a policy and financial issue that probably is above that pay grade.

Mr. WOLF. Well, I am not optimistic about the future of having the resources in the sense that our country is broke. I mean, we are broke. It seems that the Congress does not know it and no one else knows it, but everybody knows it. It is sort of like what are we doing.

Today my staff just showed me an article. A UN panel will next week recommend that the world ditch the dollar as its reserve currency in favor of a shared basket. Well, that would be disastrous. We lose our triple A bond rating, according to Moody's, in year 2012.

And it just seems to be kind of, the headlines today, the fed bails out another 1.2 trillion, and the speculation is that the deficit that will come out tomorrow, CBO's figures come out tomorrow, that the deficit for this year will be $2 trillion.

And when I see some of this money going out, if we could only put it in science and math and science and physics and chemistry and biology and cancer research and research on autism and research on Alzheimer's and the things that really, you know, help the nation and, yet, it just seems, you know, I do not know if it is going to be the money.

And everyone has testified since, and I commend the Chairman for having these hearings, everyone has said it has been great for the stimulus and they are looking forward to the money and what will it be on the out-years.

You know, I just, unless there is a—maybe what my mom and dad taught is that, you know, you do not have to save. Maybe you can just go down to the Bureau of Engraving and just print money and get a lot of paper and a lot of ink and just keep things running and running and running.

And I have always thought it was a zero sum game, but apparently maybe—so I think there are going to be some long-term problems.

I have a bill in with Congressman Cooper. We put it in yesterday. There were 26 Republicans on the bill and 26 Democrats. Interesting, but we hear that there is no bipartisanship in this place and here it is probably happenstance that we had 26 and 26.

If we put every spending program on the table and set up a bipartisan commission, but also to look to make sure that we have the funding for things that you are talking about—did you take the train down?

Mr. MOORE. Yes.

Mr. WOLF. When you go home, are you taking the train home today?

Mr. MOORE. Yes.

Mr. WOLF. Do not read the paper for about two hours. Go through my old neighborhood up in Philly. When you go by there, all the factories are in decay. Just look at the factories all through the Maryland area and Pennsylvania. They are all closed. The windows are broken. The graffiti all over. The trash has been dumped all along there.

You must get off at the Trenton stop. You know the sign on the bridge, Trenton makes, the world takes. For the record, what does Trenton make? It does not make anything. It has a violent MS13 gang problem.

So economically we need to put more money into the things that you are talking about and have a renaissance for this nation to do precisely what you are recommending. And, yet, I fear that the way this situation is going with regard to the spending that there will be additional tremendous spending, but it will not be in the area that what you all talk about. And for our children and grandchildren, it will not be very, very bright.

Doctor, this problem was around for a good while on the coordination. And should this Committee put legislative language in requiring that there be one office that coordinates between NASA and NOAA or do you develop in the White House—and the White House Office on Science, I think, is relatively ineffective.

I do not know how many people. Does anyone know how many people are in the office down there? They actually recommended in the last Administration that their budget be cut. I think they are down to a handful of people. Does anybody here know how many are in the office? Do you know how many are in the house? Are you with the office?

Ms. SHANLEY. No, but I thought there were about 40.

Mr. WOLF. Forty. Yeah, 40. And then two years ago, Marburger recommended that it be cut, cut, reduced, cut. Maybe we need a National Security Council, but a Science Security Council, not necessarily in the White House, but sort of to be the coordinator because when you do have scarce resources, you have to make a decision, you know, as a business or an individual what are you going to do, and one to advocate for the sciences, but also to be able to make these decisions.

Would that make sense? So we are not solving the world problem, but this problem, should this Committee put language in recommending that there be a mechanism established within 60 to 30, 90 days to deal with this issue because this issue is not new? It has been going on when the Republicans had Congress. I was on this Committee and it was still a problem then.

What do you think should be done? Should we legislate in the appropriations bill something to require the coordination and what do you think about the concept of having a Science Security Council that can coordinate this, because we do now—Secretary of State does international relations, but we have the National Security Council that sort of coordinates these between with regard to the different agencies. So it is really two questions and if both of you have any thoughts.

Mr. ANTHES. Well, I hate to recommend legislation without thinking more deeply about it. But, you know, we recommended, the Decadal Survey recommended that OSTP develop a plan.

Mr. WOLF. And has that been done?

Mr. ANTHES. No.

Mr. WOLF. And how long has the recommendation been on the table?

Mr. ANTHES. Well, 2007, so two and a half years or whatever.

Mr. WOLF. That is like Waiting For Godot. You remember that play, Waiting For Godot? Godot never shows up.

Mr. ANTHES. Well, I think from what you are saying and what I have heard is that OSTP needed to be strengthened, not diminished. And I think there is hope that under this Administration OSTP will be strengthened and can take this on.

But there are probably a variety of ways that this plan can be developed, but we really do need a thoughtful national plan to sort out the roles of NASA and NOAA on long-term sustained climate observations.

Mr. MOORE. I think that we recognize that there is a mismatch between the responsibilities and capabilities of the different agencies and that sometimes the largest of ideas like climate can fall through the smallest of cracks in Washington I have discovered.

And sometimes the smallest of ideas will not fall through the largest of cracks. I have never quite understood what happens.

But clearly we have got to get the house in order, the government in order in terms of handling this question of climate and earth observation. We do not have it in order.

Mr. WOLF. And how long has it been a problem?

Mr. MOORE. Oh, I think for at least a decade.

Mr. WOLF. And sometimes you have to give one person the responsibility. If everyone's job is to take the trash out, no one takes it out.

My sense is it may not be a bad idea for the Committee to put language in directing the Administration to have a mechanism to kind of coordinate.

CHINA AND GLOBAL WARMING

Okay. I think there are a couple of other questions. The other question, with regard to global warming, how much of a factor is China and how successful can we be in resolving the problem, however it should be resolved, without having the active participation of China and also India, but particularly China?

Mr. MOORE. China passed the U.S. in terms of total carbon emissions about 18 months ago. So as a country, they are the largest emitter now on the planet. Their per capita emissions are still much lower than our per capita emissions. But as a nation state, they are the largest emitter right now.

That is I think primarily for two reasons. They have had a very rapidly growing economy and, hence, an energy system that has been expanding. And the primary source of electrical power is coal. And coal produces more CO_2 per energy unit, so it is a less efficient fuel, if you will, than natural gas. So their——

Mr. WOLF. I heard they put a new coal power plant when I was there in July every week to——

Mr. MOORE. Every week, right. I think it is about every week with a 300 megawatt power plant was coming on. But I am not positive about that. But they are the largest emitter. It is a very intensive economy. It is based on a large electrical power plant growth employing primarily coal.

Now, what could be done if there are ways in which we are going to address carbon either with cap and trade or with a tax or some regulatory means, then I think it will encourage technologies to offset that CO_2 emission.

And one of my dreams, and perhaps it is just a dream, is that the U.S. leads the world in carbon capture technology and then we have something to export other than McDonald's.

Mr. WOLF. Does it make sense insofar, and, Doctor, I want to get to you too——

Mr. MOORE. And I would like to see that built in Trenton.

Mr. WOLF. Yes. Well, I agree. Does it make sense to do a cap and trade or does it make sense to do—there was an article in the Washington Post by a fellow from Denmark, I forget his name now, that we, rather than doing that, put more money into research and development.

Do you recall the gentleman's name? Bjorn. Either of you may know of him. Is he controversial in a good sense? I mean, Brad Pitt is controversial. I mean, is he credible?

Mr. MOORE. I do not think so.

Mr. WOLF. You do not think so. Okay.

Mr. MOORE. No.

Mr. WOLF. Well, his recommendation says more money into research and development to have green technologies——

Mr. MOORE. I think that is legitimate. In looking at his full portfolio of ideas, I find many of them suspect and they change rapidly.

Mr. WOLF. Are you familiar with that idea that he——

Mr. MOORE. But I think the idea of plowing money into green technologies, we ought to be pushing very hard in my view on renewable resources, solar, wind. I mean, the United States has a wind belt right across the middle of the country.

I think one of the challenges for our technology is as we go to alternative energy systems, we have to restructure the electrical grid so that it can handle these types of energy sources that may come on and go off.

Mr. WOLF. I want to give the doctor a chance at it, but you did not answer the other question of how—you talked about China, but can you solve the problem without China being an active participant? No, Dr. Moore. They will not pick up your nodding. You have to actually verbalize.

Mr. MOORE. I think you have to have all of the major emitters involved.

Mr. WOLF. Okay. And the very problem is we have begged China to deal with the issue of Darfur and rather than solving the issue, the genocide in Darfur, they are developing genocide in Darfur by selling weapons to the Janjaweed and to the Sudan government that is doing the terrible things.

And we have genocide that has been going on for five years. China goes to Darfur and says what they are going to do is build a new embassy and a palace for Bashir who has been indicted by the ICC.

So I guess the point I worry about is you can talk about these things intellectually, but China, and if you—have you been there lately?

Mr. MOORE. Yeah. Yes.

Mr. WOLF. You can see. I mean, they are pulsating. Their economy is just—and I see no indications that they are going to slow down because if they do, they are worried they are going to have riots in the street and the government will be overthrown. And they have great unemployment out in the rural areas. So I think they are going the other way. And so I think without having something, whatever it is, that they participate in would be very difficult.

Doctor, do you have any comments?

Mr. ANTHES. Well, let me just be brief because Berrien said it, but let me just summarize it in my own words.

No, the U.S. cannot solve CO_2 emissions, greenhouse gas emissions by itself. I think we are roughly a quarter of the world's emitters. Nevertheless, that does not mean we should use this as an excuse to do nothing.

Mr. WOLF. I agree.

Mr. ANTHES. We should——

Mr. WOLF. But look at the other side, though. How significant is China and then a little bit India in the solution?

Mr. ANTHES. Well, they are big. They are a very big part. I think we can lead the way in reducing or leveling off our emissions, in a way that will not hurt the economy by investing in renewable energies that we can then export to countries like India and China. So I do think we need to set an example by doing the right thing, and at the same time doing the thing that is right for us, which is getting into the development of renewable technologies that we can create jobs and then export, and help solve the other countries' problems as well. So it is not, it is not an either/or situation. I think we can do right, and do right by us.

Mr. WOLF. But you are saying that we do need China and India to participate?

Mr. ANTHES. Absolutely.

Mr. WOLF. Because if you have a cupboard and there is mice in the house, and your half of the cupboard you clean every night. You put Mr. Clean in, and very clean. The other side of the cupboard is China, and they just put in crumbs, and candy, and do not put the lid on the cake. The mice are coming. I mean, you can keep it as clean as you want to be on your side but, and so I think we need to make sure that they are participants. And I really see them not being willing to. And I really worry that what we may very well move on, that this could become such a political, I would hope that the whole issue of global warming is really resolved by the scientists and not by the politicians. We see how great the politicians were at solving the AIG problem and they are all on television now saying that they did not know what was in it, and this and that, and that. I mean, I think we need scientists, real scientists, people who are honest, ethical, decent, moral who are basing their decisions on science to come up with some of the solutions. And then I think there needs to be pressure, both from a positive and a negative, on China. Chinese people are wonderful people. I mean, they want freedom. They are thirsting for freedom. And so, perhaps this government will collapse and we will see freedom in our lifetime, the way of the Berlin Wall. But to make sure that China participates. And also, we cannot forget India. We respect and understand how they want to participate and have opportunities for their people, but we also want to make sure that they do it in an appropriate way and are participants. And let us hope that if we bring the, do you want to say something?

Mr. MOORE. Yes, very briefly.

Mr. WOLF. We bring, because I am getting ready to offer an amendment to this bill to change the sign over the river to say, "The world makes and Trenton takes." So I will hold off on that amendment to see if we can get Trenton to buy the place to put them, but.

Mr. MOORE. I would prefer the sign to say, "Trenton makes and the world buys," rather than takes. Two things about this carbon dioxide problem that are very, very important and why this Earth observation is so critical. In order to stabilize the concentration in the atmosphere of CO_2, and my testimony talks to this. If you stabilize the emissions, and we are far from that. Suppose you could stabilize magically, we wave a wand and tomorrow the emissions stabilize. The concentration in the atmosphere would keep right on going up. In order to stabilize the concentration in the atmosphere, which is what everything is really all about, you have got to drop emissions by 80-plus percent. So this is a, and we are going in exactly the opposite direction as a planet. So in order to stabilize the concentration in the atmosphere you have got to pull the emissions way down.

Secondly, once you stabilize the emissions in the atmosphere, climate will not instantaneously stabilize. We have already kicked off a set of changes in the climate system, such that even after stabilizing the concentration in the atmosphere temperature increases will continue. The temperature, put it this way, it lags the greenhouse gas. You have set in motion melting the Arctic sea ice. That is going to continue right on, even after you stabilize the CO_2. So this is a very, very tough problem. And it really requires, I think, everyone, everyone on the planet to address it.

Mr. MOLLOHAN. Thank you, Mr. Wolf. Mr. Honda.

MR. HONDA'S QUESTIONS

Mr. HONDA. Thank you, Mr. Chairman, and welcome. Thank you for being here this morning. We get a lot of information on scientific data, we get a lot of information on different cycles and how they all interact globally. And a lot of these things have been affected by human behavior. And I think that what we are talking about, or alluding to, is human behavior again in the form of policy and international cooperation, or the lack of cooperation. Leadership or lack of leadership. Can you talk to us a little bit about it in the context of human behavior? How we can move this country to a point where we become not only a nation that is responsible?

We should have started earlier. And from your point of view, you have seen a lot of things happen. And you have a context of science and you have the lenses of the kind of thing that you would understand coming from that point of view, have some critique of the process, human process, political process, of this country when it should have started. How should we start now? And what are the barriers and obstacles to international cooperation. Because, let us face it, there is mistrust of us and there is mistrust of them. And so moving, addressing that as we watch the cycles continue and change and creating, so we know it is going to be creating. How should we move as a country in terms of our national policy relative to human behavior and political, and policies and address that?

Mr. ANTHES. Wow. Maybe we should ask some psychologists here or some religious leaders.

Mr. HONDA. No, because let us face it, the last international conference, the countries that came together said let us wait until the country has another leadership because we know that until that happens they are not going to commit themselves to any long term pathway until the other place came in. And so, we are prepared to have to have so many other countries thinking and their desire for us to be involved. And I know what I heard you say, that we cannot solve this problem without cooperation of the other emitters. So what is the human dynamic that we as policy makers need to embrace as we move forward? Knowing full well of the academic, scientific things that are in play right now. And the devastation that is occurring right now. And do we continue to play our fiddle while Rome burns, or do we look at some sort of movement that moves the spirit of trying to solve the problem globally and domestically?

Mr. ANTHES. Well, I think this gets to my answer to Mr. Wolf's question, about can the U.S. solve the global warming problem by itself. No, but we can be the leader. We can take the high road. And we can start taking actions and set an example for the rest of the world that will appeal to the best qualities of human beings, not the worst. And so I think this is a leadership problem and it involves leadership at the top, but more than one leader. And it is to appeal to the best side of human nature rather than the side that says it is not my problem, let us just wait for the next generation, the next administration, the next election to solve it. So I think it does take leadership, and to appeal to the highest aspects of human nature.

Mr. HONDA. Then what is the next step in order to engage? We behave responsibly. Now what is the next step in engaging the other countries to overcome the obstacle of this perception that we have of mistrust that we have developed over the decades?

Mr. ANTHES. Well, this involves, again, starting out by being a leader and setting the example, and then negotiating. And I am not an expert in that. But if you do not take the high road yourself you do not have much of a negotiating position.

Mr. HONDA. So do you have colleagues in the other countries that we mentioned of like mind and spirit?

Mr. ANTHES. Absolutely.

Mr. HONDA. And are there discussions around this dilemma of, we have met the enemy, the enemy is us, and how we get around the politicians and have the politicians understand that our behavior sometimes may be the obstacle? And how do you create that pathway for us to be able to move down so that we can develop this road of competence? What is the mechanism to do that? And, I mean, if you know the other folks you talk to them, I am sure.

Mr. ANTHES. Well, the scientific community is pretty much united on these issues internationally. There is not a U.S. science and a French science and a Chinese science.

Mr. HONDA. Right.

Mr. ANTHES. Science is science. And so I think our role is to provide you all with the best science that we have. It is your role to establish the policies as governors and to work with the rest of your counterparts to try to help solve these political issues.

Mr. HONDA. You know, the Chinese emperors used to have their advisors. And they gave the best advice at the risk of their lives. Here we call them kitchen cabinets, and we are supposed to give the best advice that we can to our policy makers. As knowledgeable, intelligent cadres of folks in all these countries come together, would there not be a statement that the community, the scientific community, can make besides saying there is no Chinese carbon cycle, there is no U.S. carbon cycle? The sinkholes are not, you know, they are all India?

Before we had the Cold War ending we had scientists from around the world getting together and saying, “This is madness. Stop.” Where is the scientific community on that, to help our policy makers be moved to do something in a timely manner?

Mr. MOORE. Oh, I think that there are two very prominent levers, if you will, or very prominent statements. The last four assessments of the Intergovernmental Panel on Climate Change reflect the very best thinking on the science, the impacts, and the mitigation strategies. And those are assessments of the best thinking of the international scientific community. And so I think you could look to the Intergovernmental Panel on Climate Change as the gold standard in terms of our contribution.

And the second in terms of an additional activity I think on this issue of Earth remote sensing, it after all is remote sensing of the planet. We have partners around the planet. And I think that it, and it was actually an initiative of the previous NOAA administrator, the so called Global Earth Observing System of Systems.

Mr. HONDA. Right.

Mr. MOORE. I think that type of activity, if it is actually funded and not just a set of meetings that are held with nothing of no consequent coming out, might be a very real way forward so that it would be, it would reflect U.S. leadership in an international context. But at the end of the day, we have to begin to put things in space. We cannot just plan and plan and talk about it. Just as at the end of the day we have to begin to change the energy system. We can make plans forever. But if we do not begin to execute, carbon dioxide is going to continue to increase in the atmosphere and we are not going to know what is happening.

Mr. HONDA. The testimonials written here divided the comments into scientific information and human behavior. And I still get answers in terms of human behavior embedded in more science. And I guess I am just looking for someone to say, you know, if we go to war we lose. We have lost the battle. If we wait too long and do not say what needs to be said, then the political leaders who depend upon information will be lacking. Because when we are taught to be science students we are driven to take notes, observe data, record it, and make a conclusion. I have not heard a conclusion that is embedded in the direction of human behavior relative to how we use all this information in terms of moving towards cooperation. I mean, it is said you cannot do it alone. That is a given, I think. I would hope that is a given. That we need to engage India and China, we need to provide that leadership because, that is the right thing to do.

I know what I want to hear. It probably is obvious. But, you know, sometimes we have to hear from the community that says we did all the study. We need more money for the other studies to embed more information. But how much more information do you need, you know? Papa Bear, Mama Bear and Baby Bear already knew someone slept in the bed. And the conclusion was, you know, someone was here.

It may be that you are, your position is such that you cannot make any other statements other than this. But I am trying to drive you to a point where——

Mr. MOORE. I think that this particular problem had a period of as it evolved where there was a lot of disinformation brought into the system.

Mr. HONDA. Right.

Mr. MOORE. And the reason is this is a very big problem. Fossil fuel, look at the Antarctic ozone hole and that involved fluorocarbons in spray cans.

Mr. HONDA. Right.

Mr. MOORE. And look how tough that was. Fluorocarbons in spray cans is not in the center of the economy of industrialized countries.

Mr. HONDA. Right.

Mr. MOORE. Fossil fuels are. They are right in the center of economic development. And therefore you are right at the core of the fabric of industrial society when you are talking about energy. And as a consequence I think that there was a period of time where there was a lot of disinformation. Most, at least half of our citizens in the United States still think that it is just bogus. And so I think that we have to really come to grips with the nature of this problem. And then we have to say it is not all that bad. We can actually do something about it. The color of money is green, what is wrong with that? And so that we begin to move from problem identification to doing something about it. And that involves jobs, it involves redoing the energy structures, it becomes more efficient. I think that there is a real opportunity here for the United States to really execute leadership.

Mr. ANTHES. I do not know if this is what you are looking for, and I am not trying to match that, necessarily. But let me give you a simple, personal recommendation, not as representing anybody. I think the administration and Congress of the United States should take a leadership role internationally working with other nations to reduce the global dependence on carbon as a source of energy. And do so by setting an example, and do so by in a way that it does not disrupt, it does not disrupt our economy but rather builds it. And I think this is a serious issue for society of the whole world. It is not like an asteroid is going to hit us next week or next month. But in the next generation and the generation after that it is very serious. The western governors already know it is serious and are working, and really want to know what is going on with the water cycle in the west. And so they want the information right now for mitigation purposes, for adaptation purposes. But if you want a simple answer I think we need to take a leadership role in getting us off the carbon, carbon as a source of energy.

Mr. HONDA. Last question, Mr. Chairman. These regional leaders experiencing these kinds of natural occurrences, can they find other natural occurrences that are similar in other parts of the country, other parts of the world, and develop partnerships in working with each other?

Mr. ANTHES. I am sorry, I missed the first part of that.

Mr. HONDA. If our western states' leadership understands the kind of natural disasters that they are going through, and they understand the dynamics and causes, is it reasonable to look for other natural occurrences in other parts of the globe and create alliances so that this leadership and help and connectiveness would pay off in the long run so that we start to understand that we are in the same boat. I do not care if the hole is in the front of the boat and I am in the rear, the boat is going to sink. So, I guess it is like creating sister cities.

Mr. ANTHES. Well yes.

Mr. HONDA. Have we thought of that?

Mr. ANTHES [continuing]. Hurricanes are not important to the Western United States but they are very important to the Southeastern United States. And they are also important to China, to Taiwan, to the Philippines. They are important to Australia, tropical cyclones. So there is another example of a piece of this global warming problem that needs to be, that can bring people together.

Mr. HONDA. But if our states like Montana have leadership there that understands coal and coal research, clean research around coal, they can partner with other parts of the world like China, where coal is produced, and we would like them to sort of understand that you can do the coal and here is the technology. And we can sort of figure out how we can solve your problem and our problem, and then address the world problem. I am looking for ways to link so that we do not sink, and that we do not say "them" and "us." Because I think USA really spells out US ALL, right? And so I am just trying to push the, beyond just the science button. The human, because you touched the, you said human behavior. Thank you.

ORBITING CARBON OBSERVATORY

Mr. MOLLOHAN. Thank you, Mr. Honda. Gentlemen, just to tie up the Orbiting Carbon Observatory questions, you are clear that you did not think that we could rely on Japan's Abuki carbon mapping spacecraft or the European weather satellites that we cannot and we should not do that. And is that a fair summation of your testimony?

Mr. MOORE. I would say that in evaluating what to do right now about reflying the orbiting carbon observatory or not, we need at least to evaluate what we are able to get out of the capabilities that are on orbit right now. In my view, they certainly are valuable today but they are inadequate for the challenge. And therefore, we are going to have to decide to do something. But you need to at least know what you have on orbit right now as you evaluate what is the something that I am going to do. And how much of a difference will that make? So we need to evaluate what difference would an orbiting carbon observatory style of technology make to what is on orbit right now versus another type of technology. And then that helps inform the decision. And I think that is what NASA is doing, is they are looking at what are the capabilities of what we have on orbit right now? How long would it take to do an alternative mission, OCO or an active mission? And how much would it cost? So all of those are part of the decision. I would trust that NASA could do that analysis, particularly engage the scientific community.

Mr. MOLLOHAN. Okay. So you are saying, this is your opportunity to express an opinion about that and I am giving it to you. But you are suggesting that you would be more comfortable expressing, making that judgment and expressing that opinion after

NASA has had an opportunity to complete the review that they have announced?

Mr. MOORE. Yes. And as I have indicated, I have a personal opinion, is that I think that we should move forward with the active mission. But I certainly think that——

Mr. MOLLOHAN. Now when you say——

Mr. MOORE. I am capable of changing my mind once I see what NASA concludes after they look at this question.

Mr. MOLLOHAN. Yes. Dr. Moore, when you say the active mission——

Mr. MOORE. Yes?

Mr. MOLLOHAN. Active, you are talking about a——

Mr. MOORE. Using a, where you actually shine the light down from the spacecraft using a laser——

Mr. MOLLOHAN. A laser. A laser.

Mr. MOORE [continuing]. As opposed to using the reflected sunlight from the sun.

Mr. MOLLOHAN. Yes. Okay.

Mr. MOORE. And that, and it is in that context that I use the word active.

Mr. MOLLOHAN. Okay.

Mr. MOORE. That you are actually shining, the spacecraft is providing the light, if you will, to probe the atmosphere as opposed——

Mr. MOLLOHAN. And what are you saying about the active mission?

Mr. MOORE. And I would believe that would be, to me that is the logical next step.

Mr. MOLLOHAN. What is the active mission?

Mr. MOORE. ASCENDS. A-S-C-E-N-D-S.

Mr. MOLLOHAN. All right, ASCENDS. So you would want to, you would want to accelerate ASCENDS from a priority position between 2013 and 2016, and a second tier mission in the decadal recommendation?

Mr. MOORE. Well I, right now I——

Mr. MOLLOHAN. I do not want you to say more than you are comfortable saying.

Mr. MOORE. I think that in terms of then going, I have said what I would think the logical next step is, which is this active mission.

Mr. MOLLOHAN. Okay.

Mr. MOORE. The issue of acceleration, I think, that really requires this analysis of what is on orbit, and how much does it cost, and how quickly could we achieve——

Mr. MOLLOHAN. Okay. It merits a process that is underway. Thank you. Dr. Anthes, do you have any more thoughts on that?

Mr. ANTHES. No, I think that is right. And these things are never simple. You look at one mission, like a Japanese mission, versus OCO, versus ASCENDS, they are never identical. So they are measuring different aspects of the same problem. And so you cannot say, "Well, we can just rely on the Japanese." Even if it was a U.S. mission, laying aside the politics and whether we can rely on foreign countries. These missions are never the same, whether it is VIIRS and MODIS. They are similar, but they are not the same. And they have different costs.

Mr. MOLLOHAN. They just do not do the same thing.

Mr. ANTHES. They do not do quite the same thing, and they are, they have different resolutions, different high def versus low def kind of thing, and so this is why you need a thorough study, a trade study, and looking at costs and everything. And if you move ASCENDS up what is not going to get done? You know, because you have ice measurements are important, soil and moisture are important.

Mr. MOLLOHAN. It all has to be looked at in context.

Mr. ANTHES. It all has to be looked at.

Mr. MOLLOHAN. Well let me ask you this, and this is just a quick question and answer I think, do you have any informed judgment if NASA were to come forward and say, "Gee, we ought to redo the OCO," about cost and timing? Just how much it would cost and how long it would take?

Mr. ANTHES. If they did this?

Mr. MOLLOHAN. Yes, if NASA recommended that?

Mr. ANTHES. Yes, I would support it.

Mr. MOLLOHAN. No, I say, do you have an informed judgment about how much that would cost and how long it would take?

Mr. ANTHES. Study?

Mr. MOLLOHAN. No, sir.

Mr. ANTHES. Oh, you mean the mission, redoing it?

Mr. MOLLOHAN. Implementation.

Mr. ANTHES. I have heard two, two to three years.

Mr. MOLLOHAN. And——

Mr. ANTHES. From a go decision it would take two to three years to get another OCO try, another launch.

Mr. MOLLOHAN. And cost?

Mr. ANTHES. About three, let me just tell you, let me give you the cost this way. About twice the AIG bonuses.

Mr. MOLLOHAN. Now that is going to require that I do mathematics. And I have two scientists in front of me that probably did really well in mathematics. So I am going to rely upon your calculation not mine.

Mr. ANTHES. Okay.

Mr. MOLLOHAN. What would that be?

Mr. ANTHES. I hear the AIG bonuses are about $165 million. Twice that would do another OCO. And this gets back to Mr. Wolf's question about, well do we have the money to do these.

Mr. MOLLOHAN. Well, that is another issue. We will grapple with that. But, thanks. So you are saying about——

Mr. ANTHES. A little over $300 million, yes.

Mr. MOLLOHAN. $300 million, okay. You, Dr. Anthes, in your closing I was struck by this, your going ahead and saying it. In your closing testimony, your last paragraph, you say that you have noted that the NRC is starting a study, assessment of impediments to interagency cooperation on space and Earth science missions. I mean, hearing your testimony and hearing it today from both of you, this whole notion of who has what responsibility—roles and missions—between NASA and NOAA is extremely important. So I want to give you an opportunity to talk about that. And you are suggesting explicitly in your testimony, Dr. Anthes, that we should move forward with fixing that. And if we have the right director at OSTP then that is a good place to start, if I understand your testimony correctly. This seems like a really fundamentally important question to me as we move forward and try to be efficient and intelligent about how we deal with these very expensive systems to address this very important problem. So I would like to give you all an opportunity, and Dr. Anthes, since I am quoting your testimony, why do you not start?

Mr. ANTHES. Yes, just saying it in another way, our long term sustained climate observations, there is no mandate for either agency to do that. NOAA has a mandate to do weather observations. They are thinking about a climate service, and observations, long term climate observations have to be part of, or have to be the foundation of a climate service. But NOAA does not have the mandate for making long term sustained climate observations. They certainly do not have the budget; they cannot even support weather observations. So how do we think they are going to be able to support taking on climate observations in addition to the weather observations? NASA does not have the responsibility for long term, continuous, sustained observations. They are more a demonstration agency, demonstrate this technology, move on to the next one.

So the paradigm has to be fixed. And therefore, some agency, one agency, must be given the responsibility and the budget to do these long term sustained observations, and not rely on goodwill between the two agencies, good cooperation between the administrators of the two agencies, relying on foreign governments to chip in, and that kind of thing.

Mr. MOLLOHAN. Yes, relying on, each relying on the other to do a mission that neither has. So what you are suggesting.

Mr. ANTHES. It is ad hoc. We depend on goodwill. And there is no national plan or commitment or responsibility assigned——

Mr. MOLLOHAN. Yes.

Mr. ANTHES. That is what we would like to see.

Mr. MOLLOHAN. First things first. Dr. Moore.

Mr. MOORE. I think the difficulty is highlighted by the fact that we made the recommendation in January of 2007 to OSTP. We met with OSTP to endorse the recommendation, to provide the background thinking, and nothing ever happened. And I realize that any form of reorganizing government one can be dueling with windmills and waste a lot of time. But it does seem like to me that this question of climate, which was not really on the table thirty years ago when NOAA was formed, it really is a new topic, relatively speaking, relative to the structure of government. And we just do not have a system that is in place to do something about it.

I do think that there is a chance. I know Professor Holdren, who is going to be the new head of OSTP.

Mr. MOLLOHAN. That was my next question.

Mr. MOORE. I have a great deal of faith in John Holdren. But whether or not he can take this big problem on, from the platform of OSTP, remains to be seen. It is extremely important and needs to be done, though.

Mr. MOLLOHAN. Well, he can probably take it on if the President tells him to take it on.

Mr. MOORE. That is true.

Mr. MOLLOHAN. You say, you suggest you know Dr. Holdren. Have you ever heard him opine on this issue?

Mr. MOORE. I have certainly heard him discuss the issue of climate. I have heard him speak about that repeatedly, and his understanding of the climate issues particularly as they relate to energy systems. I think the question of earth observation has not been something that has been as much a part of his background. And I think that is where we really need some focus. Because that is what falls between NOAA and NASA. It is the implementation of the observational program.

Mr. MOLLOHAN. What is his concentration? Is he an Earth scientist?

Mr. MOORE. He is a physicist, and I think his concentration in recent years has been on energy systems.

NPOESS SATELLITE PROGRAM

Mr. MOLLOHAN. Well, that should hold him in good stead. Dr. Moore, you were recently quoted as suggesting, and this kind of relates to your previous testimony, of accelerating the—well, let me ask you if this is accurate. Suggesting that ASCENDS, the laser sounder that you have talked about, currently slated for the 2013 to 2016 time period, should be accelerated. But you have had a more thoughtful answer here, so let me not go into that.

For several years now, this Subcommittee has had to wrestle with large cost overruns on the NPOESS satellite program and its VIIRS imaging instrument. Dr. Moore, you recently participated in a major review of this program. What recommendations can you share with us today based on this review? And how does this affect the future use of satellites to study, to monitor, and predict climate change? What should we be doing the same? What should we certainly be doing differently?

Mr. MOORE. Well, this is obviously a very big problem. And it is not isolated to NPOESS. It is not isolated to weather satellites. It seems to be a problem that cuts across government. The Department of Defense, NASA, other missions, the NPOESS program as you have mentioned. I think there are three things that I have taken away as I have worked on this and worried about it.

First of all, I think that management by a committee, if you will, is very difficult. So if you have one or two, I mean, if you have two or three agencies involved in the management structure that is extremely difficult. And so I think that the Integrated Program Office as a form of management is problematic.

The second thing is that there is almost an awkward or, insidious is perhaps too strong of language, relationship between the various branches of government. So that when one has a program one says it is going to cost X, knowing full well it is going to be 2X. And Congress, who is worried about money, might be willing to go along with the X because it means less pressure on the budget. But they probably know it is going to be 2X, too.

Mr. MOLLOHAN. I just want to stop you. I totally agree with that. We saw that in spades with regard to space station. Every year they came in here and testified, "Oh, this is the budget this year and we can do it." And you knew somebody had told them that, they knew it, and we knew it. So we were complicit in it. I used to sit down at the other end of the table and think this is crazy.

Mr. MOORE. And, and my community is partnered in this because I, "Oh sure, we can do that. We have the technology at hand." Knowing, "Well, maybe not. But if I do not get the proposal then I will not have the technology." So there is an insidious relationship that I——

Mr. MOLLOHAN. We bring these three agencies together, the Defense Department, and NASA, and NOAA. And they have different cultures, different values with regard to budgets and money, and different experiences in getting additional money when the inevitable cost overrun comes along.

Mr. MOORE. Right.

Mr. MOLLOHAN. So that is difficult. But we are going to have these combinations in the future. I mean, just for a lot of reasons, trying to achieve efficiencies I am sure. Or, maybe we will not if it is impossible to do. But I would like for you to address this question a little bit from the standpoint, and Dr. Anthes you as well, from the standpoint of the different cultures, the different modes of operating, the different resources, availability of resources. And then, not so much dwell on the problems, but address them. But how should we do these expensive missions? How should we do them better in the future?

Mr. MOORE. All right. I think the, taking the NASA/NOAA, I actually think that the way in which we implemented those programs in the past, that is the polar orbiting satellite system that was NOAA run, for essentially NASA served as the procuring agency if you will and then turned those over to NOAA.

Mr. MOLLOHAN. The developing agency?

Mr. MOORE. The developing agency. The difficult with that with regards to NPOESS is that I think the Department of Defense was not comfortable having NASA have that role. And so it created this new object which did not work.

I think that we do not have a good model on how to solve that. It is either going to be to use the NOAA/NASA relationship with the Goddard Space Flight Center to handle this NPOESS program or you are going to have to use a Department of Defense system. I do not know quite how to go forward with that because I think it is a fundamental problem in the way we actually structured it to begin with.

The other thing that I think is right at the heart of these cost growths, we fib when it comes to the technology readiness. We are, shall we say, overly optimistic. And we do that for two reasons. One, we want to go forward with the program. And two, we have never adequately developed a funding mechanism to develop the basic technologies before the mission begins. There is this tendency, "Well, I will develop them once I begin." So we have been unwilling to actually put the up front money on the table to develop the kind of technologies. And I do not think that is restricted just to the space business. I think there has been a tendency in the country of being unwilling to invest in the kind of technologies that this country needs until we actually need the technology, and then we kind of do it on the fly.

Mr. MOLLOHAN. Okay, thank you. Mr. Bonner, you have questions? Mr. Wolf.

Mr. WOLF. Yes, Mr. Chairman. I just wanted to comment. It is really not a question unless they want to answer it. You will not solve the problem with the current office in the White House. And the bureaucracy will be such that there will be the competition between the Defense Department of its environment, and of NASA, and of NOAA. There will be the weakest agency will be the least effective. That will certainly be NOAA. And then it will sort of move up. NASA, because of contractors and things. And then next you will go to the Defense Department that will drive it. The Interagency, and I do not know, what is the good doctor's background? Has he been in government before, who is going to head up the office? What is his background?

Mr. ANTHES. He is a professor at MIT.

Mr. WOLF. Yes.

Mr. MOORE. Harvard.

Mr. ANTHES. Oh, Holdren, Harvard, okay. Sorry.

Mr. WOLF. And has he been in government before? Has he been? Well, he will probably get chewed up, probably relatively fast. We had a situation a number of years ago, violent gangs running through the country. Was that the FBI's responsibility, or was it the ATF's responsibility? Or was it the DEA's responsibility? Or was it the Marshal Service's responsibility? This Committee put together a Gang Intelligence Operation that coordinated them all, and gave the decision to drive that issue to the FBI. Until that time, each agency comes in to gather whatever it can for its own area. So you will not solve it. And I would predict that it would continue unless you give one person, one agency, the responsibility with the ability of the support of the White House to kind of deal with that.

Years ago, I was at the Department of Interior in a previous administration. There was great competition, who was going to deal on the coastal zone issue. The coastal zone issue was clearly in the Department of Interior because that was where everyone in Interior felt it should be. It was clearly in CEQ because that is where CEQ thought it was. And of course, the people at Commerce and NOAA thought it was clearly in the Department of Commerce and NOAA. And competition on just who is going to have the oversight over coastal zone management. So this is a bigger issue. And I think until we have one person, one agency responsible generally, and this good doctor will come into town and think that he can call up and have things. There will be things leaked to the press, or leaked to this group, and the end result was nothing will happen. But thank you both for your testimony.

Mr. MOLLOHAN. Thank you, Mr. Wolf. Mr. Ruppersberger.

COST

Mr. RUPPERSBERGER. Sorry, I had three committees at the same time. So, I know the Chairman talked to you about the issue of cost. We have DOD, and we have intelligence, and then we have NASA and we have NOAA. And there is not enough money for everyone to be there. And we need to somehow have more dialogue so there is not repetition. And the intelligence or DOD in science might be able to use some of that. Now you may get a push back from DOD and intelligence. I am on the Intelligence Committee and we are going to say it is classified. So sometimes we have things that are overclassified, also. But with that mind, I know you have already answered that question. The decadal survey, I noticed that in your example that the decadal survey estimated cost of the James Webb Telescope to be about $1 billion, when it was three or four times that. And some scientists have said, basically, if we would have known the cost would be three or four times, in the billions, that we might have looked at other areas or other ways to do what James Webb does. Now, we know we have in place and we know we have new technology coming forward. How confident are you that this survey you have now as it relates to the cost factor, because that is what we do as appropriators, is where it needs to be?

Mr. ANTHES. You mean in estimates of the cost?

Mr. RUPPERSBERGER. Cost.

Mr. ANTHES. Well, I think that they were pretty good when they were made. And they were as objective as people could feed us the information. But as my colleague says, once a mission is funded it seems to take on a life of its own and the budget suddenly goes up two or three times once it is funded.

So I think something needs to be put in place that before a mission is——

Mr. RUPPERSBERGER. This is pretty much exactly what I am saying, because by the time it gets to us as appropriators, it is a whole different ball game.

Mr. ANTHES. Right.

Mr. RUPPERSBERGER. And the costs are over. And so are you going to answer the question? What do you think needs to be done?

Mr. ANTHES. These are difficult to estimate costs first of all. So if they are 25 percent over, I don't hold that against them. It is very difficult. But when it is three times, four times, something is wrong.

So I would recommend——

Mr. RUPPERSBERGER. In answer to your question.

Mr. ANTHES. Yes. I would recommend something like an independent, non-advocate review of the cost estimates of these missions before they are funded. And this would be done by engineers, by people who really understand space missions, technologies, launches, and all that. And have an independent, non-advocacy review of these things that would be done before they are funded.

Mr. RUPPERSBERGER. Who would put that together?

Mr. ANTHES. I don't know. It wouldn't be NASA. It wouldn't be NOAA.

Mr. RUPPERSBERGER. Wouldn't it be a representative from NOAA?

Mr. ANTHES. It would be a completely independent group, probably funded separately. And as I say, a non-NOAA, non-NASA, non-government advocacy, even non-scientist advocacy review. It would be an objective assessment of the cost before it is funded.

And then if people were low balling the estimate just to get the funding, they would—you would have an independent check of those estimates, because right now the estimates are done by advocates for the missions.

Mr. RUPPERSBERGER. Where you would get more accountability.

Mr. ANTHES. Exactly.

Mr. RUPPERSBERGER. Let me ask you this. Is there anything in the current earth science decadal that you would change based on what you know now that you didn't know in the beginning when it came out?

Mr. ANTHES. I stand by the decadal survey and the order that it was done. I think it is important to stand by that at least for five years. And then maybe take a look at where things are. I stand by it.

Mr. RUPPERSBERGER. Okay. We are leaderless.

Mr. MOORE. Let me just add to what Rick Anthes said. First of all, I would like to endorse it. Secondly, I think that this is an area where as the Academy does these decadal surveys, that might be the time to first involve an independent cost team activity, so that the scientists are making the recommendations and in some sense setting out what their vision is for the program.

In fact, you have mentioned the fact that some people have said, "Well, if we had known this was going to cost as much on James Webb, we might have done something differently." So I think that in the decadal survey process, we need to have some better form of getting budgetary information, because that does influence the order in which you put things.

Mr. RUPPERSBERGER. No question. You know, one of the things that we have seen in the construction of satellites and with DOD intelligence side, is a constant—you start with a project and then you expand the scope.

Mr. MOORE. Yes.

Mr. RUPPERSBERGER. Another thing you see is that there have been a lot of failures recently. And we cannot continue to have these failures, because Russia and China are this close to us right now. But that their research and development phase, the budget for that has been cut at least ten percent.

But, you know, when you manufacture something in science and engineering, it really isn't manufacturing. There shouldn't be any mistake when you have done the research and development and proper testing. You know, once you are ready to go through specifications and whatever you need to know.

And this constant over budget and not on time is a big issue. But I wanted to point out just as an example in the decadal——

Mr. MOORE. Decadal.

Mr. RUPPERSBERGER. Whatever. But here you have got some estimates in there for the first phase for some survey that cannot be completed before 2016–2017. Now when that is in the actual—when that is in the actual report as the inflationary issues and the projections for funding, is it considered when that is being—when the report is being written?

Mr. MOORE. Well, what we decided to do in writing that report was to put those—to lock them in 2006 dollars, so that we had a constant dollar value. And so those numbers were in fiscal year 2006 dollars.

I think that that at least was one step that we could control. I think that all of us felt that the second way in which you could begin to control costs was to put—to start missions with an extended early phase of technology development.

And that if the mission then began to grow in costs, you could in a sense put it in the breakdown lane and not jam up the freeway with a stalled car in the passing lane. And so in a sense, you could move it to the side and then let missions that are not going through an enormous cost growth, go ahead.

I think that would encourage missions then to say, well, we don't want to go to the breakdown lane. We have got to find a way either to descope or get these costs under control.

Mr. RUPPERSBERGER. Let me ask you this. To your knowledge, has the scope and costs changed for any of the Tier 1 missions in the survey now? Following through with what you said.

Mr. MOORE. Many of them. Yes, they have gone up significantly.

Mr. RUPPERSBERGER. See that is an issue that when we are sitting here as appropriators when we are having a plan, and we constantly have the cost overruns, and then we have to make priorities on space versus other areas. And we have to maintain our space dominance, because that is one of the reasons we are the most powerful country in the world.

Mr. MOORE. Yes.

Mr. RUPPERSBERGER. And I mean from the military intelligence point of view, we have even had hearings here with NOAA and all these issues, the climate issues, that we are dealing with and the research and science. So what it does, it doesn't give us a lot of confidence in the projections, where we are going down the road. And that is difficult, because we have to have a final number when we appropriate.

Okay, thanks.

Mr. MOLLOHAN. Okay, Mr. Honda.

SCIENCE EDUCATION

Mr. HONDA. Thank you, Mr. Chairman. In the area of education, what is the most critical thing, in your view, that we need to teach the American public to get them to recognize the pressing nature of the climate change problem? And what is the most effective way to teach it? And which agencies are best equipped to take on that job? And are NASA and NOAA capable of working together on this?

Mr. ANTHES. Well, one of the problems is the politicalization—I have trouble saying that word.

Mr. HONDA. Me, too.

Mr. ANTHES. Of climate. If you look at the—there is a huge gap between what Democrats think about global warming and what Republicans think about global warming. The gap is far greater than it should be.

Mr. HONDA. Okay.

Mr. ANTHES. And there are other parts of science where—which I won't get into that there is the same kind of gap. And then this means that people are putting their political or personal views ahead of the science and maybe on both sides.

The gap between two parties, the two leading parties of this country, on fundamental physics and science and biology should not be—ideally should be statistically zero difference.

We should agree on the science. Then we can get into values and various tradeoffs and priorities. But there shouldn't be disagreement on the basic science and yet there is. So you have asked a very important question about how we at least get people of all kinds of persuasions to agree on the science and then move the debate to what we should do about what that science indicates.

Mr. MOORE. I think there is another aspect of this. And that is for very complicated things. And the earth's climate is a very complicated thing. I think a picture is truly worth a thousand words. And I think that if we had a better way of presenting what we know visually about how the planet is changing, I think that you could bring the body politic along a little bit.

In 1980, in September, the area of arctic sea ice—the area of arctic sea ice in September of 1980, was just about the same size as the 48 states. The area of arctic sea ice last September, it was as if every state east of the Mississippi had melted. All of the states from the western border of the Mississippi, they had melted and North Dakota melted. In other words, the area of arctic sea ice was that big a change.

I don't believe one percent of the body politic in the country has ever seen any of this. And yet that imagery I think would really begin to say this is not political. This is not a Republican or a Democrat, because arctic sea ice did what arctic sea ice did——

Mr. HONDA. Right.

Mr. MOORE [continuing]. Irregardless of party.

Mr. HONDA. So you are saying that we need some techniques that can record visually some of these changes so that we have not only inconvenient truth, but a demonstration of incontrovertible facts.

Mr. MOORE. Right.

Mr. HONDA. I will let that speak for itself and raise the questions.

Mr. MOORE. I think that satellite data and climate models are almost exclusively the domain of scientists.

Mr. HONDA. So can I conclude from what you are saying is that whether NASA, NOAA and the other agencies work together, they should in order to bring all these cycles together so that there will be visually demonstrable on PowerPoints and—because we have the technology and the computer power now to model all that and to show all that visually? And then fill the picture in with words and then teach——

Mr. MOORE. That is just a personal interest of mine.

Mr. HONDA. As a school teacher, I agree with you that we do a lot of talking, or we do a lot of reading. But in order to learn, we have to hit all the senses in order for us to comprehend what it is that is being said.

And some of this stuff, you know, it takes an expansion of our minds to be able to wrap it around and say how is it that permafrost, if it has started to soften up, creates so much CO_2 in an instant, along with methane, that it will—it could occur in a flashpoint in such ways that no matter what we have in terms of sequestration, it will be insufficient.

Mr. MOORE. You were mentioning earlier with Rick Anthes about human behavior. I think that that image of the earth rising over the lunar horizon, that image really changed human behavior. I mean, I think that had—it spoke fundamentally to human beings. And noone was the same after seeing that image. And I think that there are other ways in which we can go beyond just the scientific utility of space observation to really understanding what—how the planet is changing.

This wonderful record of David Keeling. And David began that measurement as part of the International Geophysical Year in 1957, the same year that Sputnik went up. And it was all part of the same enterprise, the International Geophysical Year. And the Keeling record of CO_2 increasing in the atmosphere like this, I think if that were on every gas pump on the planet and we updated it every year, that people would get it after a while.

Mr. HONDA. Thank you.

DECADAL RECOMMENDATIONS

Mr. MOLLOHAN. Okay. Thank you, Mr. Honda.

Gentlemen, I would like to discuss some of these decadal recommendations and the status of these programs.

In the first group we have CLARREO, SMAP, ICESat–II and DESDynI. And the time frame for these missions projected would be launches between 2010–2013. Give the Committee an appreciation for how they are progressing. And if there are troubles, talk about the troubles with us. And then we can talk a little bit about what—if there is a different approach.

Mr. MOORE. It is my understanding that the two that are receiving the most funding are the Soil Moisture Mission and the ICE Mission. Perhaps because without your constraints, I don't know, but I believe that the earliest either of those would be launched would be in the 2015–2016 time frame.

And the other two I think are just getting going. And I guess that would say that of the first-tier instruments that were supposed to be—that we were hoping for launch in 2010–2013, none of them will make that.

Mr. MOLLOHAN. And is this for technical difficulties? Is it the funding schedule, Dr. Anthes?

Mr. ANTHES. I would say frankly our—the decadal survey was an optimal—an optimum report and assumed everything would go well. And assumed that the budgets would be there. There would be no mission creep. That there would be—the decisions would be made quickly. And we would get started on it right away. And probably none of those things are actually true.

We certainly didn't have the budget. There is a gap, which is now around six or seven hundred million between what the decadal survey required. Now that is a gap, even assuming there were no cost overruns or mission creep. So it would be easy and fun just to say we didn't get that money and that was part of it. But it is not the only reason.

Mr. MOLLOHAN. When you both co-chaired the study, you were engaged in carefully reviewing this; is that correct? Do you still agree with the—if the order or the way these are ordered? Forget about the dates for a second, Tier 1, Tier 2, Tier 3.

Mr. MOORE. The way we ordered them within the tier was just from the cheapest to the most expensive. We reviewed the——

Mr. MOLLOHAN. Down through the whole list or through tier by tier?

Mr. MOORE. Tier by tier. At each tier, we just took the logic behind that was let us get going on the one that is least costly, because if we have a cost growth in the one that is least costly, we will do less damage than if you have cost growth in the one that is most costly.

Mr. MOLLOHAN. Just so I understand, Dr. Moore, from top to bottom, the first tier through the third tier.

Mr. MOORE. No.

Mr. MOLLOHAN. It is within the tier as you ordered them by cost.

Mr. MOORE. Within the tier it is by cost.

Mr. MOLLOHAN. And they got in the tier by importance of the mission?

Mr. MOORE. No, by technological readiness. For instance, the ICESat Mission, you notice it is ICESat–II.

Mr. MOLLOHAN. Yes, I do.

Mr. MOORE. And that was because we had already flown one. And it had technical problems. And so we thought well of those things that are—that we ought to know how to do, it is when we are making a slight adjustment off of a technology problem.

So our moisture mission had been accepted. And it was called HYDROS when it was originally accepted. And then it had been cancelled. And so we thought well that has much more—it should be much further along. The DESDynI Mission involved a radar aspect that had been studied for ten years and had almost become a mission at least three or four different times.

And so at least on three of the four, we thought these were things that are well in hand. And, therefore, we should have the least cost growth here. And the next tier were those that had a little more technology development. And then we could start on that technology development now so that by 2013 that technology would be in place.

Unfortunately, that has been—that turned out to be overly optimistic.

Mr. MOLLOHAN. Okay. What turned out to be overly optimistic is the advance technology research and development for the Tier 2 missions so that——

Mr. MOORE. I think that was one part. And then we were I had been surprised at the cost growth on those missions that we felt were well in hand.

Mr. MOLLOHAN. Okay. And you are talking about Tier 1?

Mr. MOORE. The Tier 1.

Mr. MOLLOHAN. What were the reasons for that cost growth? And this is important. It is a really important question for us to understand. It would be great if you could help us with that.

Mr. ANTHES. Well, I think there wasn't the independent, non-advocate review of the cost estimates of our cost estimates. Now we got the best information we could from experts at JPL and Goddard. And I think we got honest estimates. These were non-advocate estimates. And we are not—at least I am not an engineer myself. And I am not an expert in costing out space missions. And I have a full-time job that is not to do that.

But I think somebody needs to have a full-time job that does that, because the cost of this non-advocate review is going to be minuscule compared to the overrun of any one of these missions. And that ought to just be something we set up.

Mr. MOLLOHAN. So the numbers associated with this in your report are rough calculating?

Mr. ANTHES. I think they are better than that, because we got it from people who are objective in NASA that have experience. And so they were better than ballpark. And they had a little bit of margin assigned to them but evidently not enough. But once you fund one, you say that we are going to do this, then people start wanting to embellish the mission and add more stuff. They think we have already got it, so now let us make it a little bit better, and a little bit better, and a little bit better. And so you get mission creep.

And anyway, I don't know all the reasons. But every one of them—it seems like every mission goes way over and something is wrong. If only half of the missions were over and half were under the estimates and you had a margin, then you would say okay, well that is life. This is a real issue.

Mr. MOLLOHAN. So as the Appropriation Committee, we should be getting a very firm fix on what is the project.

Mr. ANTHES. Well, I think you should be getting—you should get evidence that these things have gone through a non-advocate cost review.

Mr. MOLLOHAN. And that they are not going to change.

Mr. ANTHES. And they may change, because we are not perfect and these are complicated missions. And some are going to go over and some that shouldn't go over. But you ought to get a——

Mr. MOLLOHAN. A little flexibility.

Mr. ANTHES. In my opinion, yes, a little flexibility. And then there ought to be people held responsible. They could lose their jobs when something goes over three times, four times what they estimated it to be.

Mr. MOORE. And we had put in the report that if missions started to grow in costs—I mean, it is in the report that they should be put in the breakdown lane until they sober up. And I think it is extremely difficult. It appears to be very difficult for the management system to put things in the breakdown lane. I think it is very difficult politically.

MISSION COSTS

Mr. MOLLOHAN. To put things in the "breakdown lane," tell me what that means.

Mr. MOORE. Well, you say all right, we are having a large mission—a large increase in costs here. We have to restructure this or we need to—before the standing army becomes a marching army, we need to resolve those technology issues. We need to resolve those technology issues that are leading to the cost growth. And let other missions go ahead that are not suffering that kind of cost growth.

In other words, if something can in a way—if a mission can use its fact that it is the first in the cube to almost grow uncontrollably, then you have a very big problem. And so there has to be some management structure that says all right, well, the technology is not as in hand as we thought. Therefore, before the mission gets a large standing army, let us work on those technology issues so that we can bring this mission back on line downstream. But let them let other missions go ahead.

And I think the psychological impact of saying oh, well, we are now parked until we get our—you know, our act together. And these other missions are going ahead. That would begin to help control the costs. Right now that just does not happen.

Mr. MOLLOHAN. Both of you are eminent scientists. From your perspective, what would be an appropriate control, one that would be effective oversight, pick up cost overruns, pick up things that shouldn't be happening, but at the same time would not be too intrusive. What would be your concept of how that might work?

Mr. ANTHES. Well, I would have this initial review of the costs, and the mission, and the requirements by experts who know how much a laser costs, and how much integration costs, and how much a launch costs, and those kinds of things. And has an ability to assess the risk of developing this laser that has never been developed before on time and within budget. And then once they give you, us, the estimate, this is a $350 million project but there is an uncertainty of a hundred.

Mr. MOLLOHAN. Well, that is the process.

Mr. ANTHES. And follow it through.

Mr. MOLLOHAN. Give me an example of an entity that would do that. Is that a government agency? Is it the Government Accountability Office? Is it a contractor that you hire to oversee it?

Mr. ANTHES. It might be a private firm that has non-government people in it and whose reputation is, you know, gold standard. That their reputation for making these estimates is that depends on their continued going forward. And then the government would contract with this private firm.

Mr. MOLLOHAN. Yes.

Mr. ANTHES. I don't know if any exist like that.

Mr. MOORE. Well I think the aerospace company has that role. I don't think it is often used as often used in the civilian side of things. I think that certainly it has not been my experience that they have been used in the earth observing side of things. But clearly some form of a non-advocate has to be looking at it.

But there also has to be the ability to say this is not going ahead.

Mr. MOLLOHAN. Okay. Let me ask you with regard to the breakdown lane, are any of these projects in Tier 1—should any of these projects in Tier 1 be in the breakdown lane?

Mr. MOORE. I think there needs to be an independent cost review of all of them. And find out where we are. And——

Mr. MOLLOHAN. Well, you all have to be very disappointed in the way this is playing out.

Mr. MOORE. I am surprised at what happened in that first tier. We gave you the rationale, or I gave you the rationale that was shared by the whole panel that well almost—because everyone has tried to get into the first tier. I mean, there was a sense of you are either there or you are never going to make it. And so we said all right, the only way in here is things that we know that had been studied to death, that had been missions before.

And we went back to JPL and Goddard repeatedly getting cost estimates. And so I think we were both surprised that something—if it had been the second tier that we had started running into trouble, I would have understood it more. But to see it happen early, I think indicates that we have a problem in the United States about executing these programs.

Mr. MOLLOHAN. So your response to my question do any of them need to be in the breakdown lane or are any of them in the breakdown lane in effect is that—well, let me ask you again. Can you——

Mr. MOORE. I think there——

Mr. MOLLOHAN [continuing]. In your judgment——

Mr. MOORE. I think there ought to be a—I think we ought be having this cost reviewed to see where we really are.

Mr. MOLLOHAN. That is fair enough.

Mr. MOORE. Otherwise I am a little too removed from it.

Mr. MOLLOHAN. Yes, fair enough.

Mr. ANTHES. I would like to state that the aerospace industry is part of the problem.

Mr. MOORE. I think the Aerospace Company, not the aerospace industry.

Mr. ANTHES. Well, I think that you need this independent group that doesn't have any dog in the fight, that is not trying to bid on the mission, is not trying to create jobs from the mission, is not trying to—you know, it is people who are retired from government or retired from aerospace industries are real experts that can do this in a totally objective way. It can't be part of the government; it can't be part of the aerospace industry; it can't be any kind of advocates.

Okay, we agree actually.

Mr. MOLLOHAN. You do?

Mr. MOORE. Yes. I was just clarifying that there is a company called the Aerospace Company.

Mr. MOLLOHAN. I actually got that.

Mr. MOORE. And as opposed to aerospace companies.

Mr. MOLLOHAN. Gentlemen, we are going to recess for just—I will be right back.

Mr. ANTHES. Actually, I have to catch a plane, so I am going to have to leave.

Mr. MOLLOHAN. Let us do this. Let us thank you all very, very much for your appearance here today. I had a couple other questions. I will submit them for the record. It has been very valuable and very insightful. I compliment you on your good work in the study and subsequent and for your excellent testimony here. We may be following up with you.

And I missed the opportunity being from the First Congressional District of West Virginia, the heart of the West Virginia high sulfur bituminous coal fields that pump out so much of that CO_2. I missed the opportunity to talk with you about that a little bit. I was going to plan on doing it off the record, just the difficulties with all that. Recognizing we need to do something.

Thank you for your appearance here today. It's very valuable.

Mr. MOORE. Thank you for your service to the country.

Mr. ANTHES. Thank you.

Mr. MOLLOHAN. Thank you.

Questions for the Record for Dr. Richard Anthes
From Dixon Butler
3/19/2009

Response by Richard Anthes
3/24/2009 11:47 AM

The U.S. Climate Change Science program includes the efforts of many more agencies than NASA and NOAA, which are responsible for all civilian satellite observations of the atmosphere and oceans. The USGS has shared responsibility for Landsat. DOD observes Earth in many ways, including non-classified Defense Meteorological Satellites and national technical means, with some data eventually declassified. These agencies, along with DOE and NSF, sponsor non-satellite continuing and occasional observations. Even school children and adult volunteers collect scientifically useful environmental observations.

1. How do these different measurements and disparate data types come together to constitute a climate change observing system, and how do they affect future Earth sensing satellite requirements?

Observations from many instruments and platforms and of different parts of the Earth system are required to understand and predict the whole system and how the parts interact. It's a little bit like understanding the health of the human body; you need to know blood pressure and chemistry, heart rate, bone density, status of the muscles and vital organs, weight, lung capacity, etc. For the Earth system, a powerful way of combining all the diverse observations is through assimilation of the observations in models. In this process the observations affect all parts of the Earth system analysis in a statistically optimum way. This is why models, data assimilation methods, and the supercomputers to run these computationally extensive calculations are required, in addition to the observations themselves.

2. How does international cooperation address climate change observation requirements, and what do you see as the proper level of U.S. leadership?

No one nation can afford all of the observations that are necessary and desirable. Therefore international cooperation and sharing of data, analyses, and forecasts are important. However, the U.S. cannot depend on other countries for making some of the most important observations, for national security reasons. I think the U.S. is doing a good job now in working with other nations on sharing of satellite and other data.

3. What improvements should be made to the U.S. Government interagency process to better achieve an efficient and effective U.S. and international climate change program?

The Decadal Survey and several other recent NRC reports make many recommendations on this important topic. These involve clear assignments of responsibilities to each agency, improvements in the research-to-operations process, adequate resources, and above all a national plan.

4. What role should adaptation research play in the U.S. Climate Change Science Program?

   Adaptation research is very important. We are committed to a major change in climate, regardless of what we do. The changes at the high end could be catastrophic unless we prepare for and adapt to them.

5. As we reach the 20th anniversary of the report of the Earth System Science Committee, of which, Dr. Moore, you were a member, what is the status and prospects for comprehensive observations of the global hydrological cycle and of terrestrial ecosystems? *NA to Anthes.*

6. The original concept of the Earth Observing System included a laser atmospheric wind sounder (LAWS); the decadal study now has a less capable laser wind measurement as the last, lowest priority mission. What happened, and does this example provide any useful insight into the adequacy of current plans for environmental satellites and the obstacles to their realization?

The Decadal survey ordered the missions by sequence, not by scientific priority. The sequencing was based on technological readiness, cost, and what other similar missions were either already underway or scheduled.

While atmospheric winds are very important for weather prediction, the technology is not well developed and the mission is expensive. In addition, ESA is developing a similar lidar-wind mission Atmospheric Dynamics Mission Aeolus (ADM-Aeolus http://www.esa.int/esaLP/ESAES62VMOC_LPadmaeolus_0.html *This mission is now scheduled to be launch in June 2009. The Decadal Survey wanted to see what was learned from this mission before going ahead with our recommend 3-D Winds mission. These are the main reasons for putting the laser wind sounding mission last in the queue.*

7. Should there be a multiagency decadal study for all of climate change research, including modeling, satellite, suborbital, and ground based remote observations, in situ observing networks, and data systems enhancements?

   This might be a bit of a stretch for a single study because of the breadth of the topic. A review or synthesis of recent existing studies on related topics might be useful.

Continuity of measurements is critical for climate change as well as for operational civil and military use. Effective measurement of some environmental parameters from space requires combinations of data from different instruments sensing different segments of the electromagnetic spectrum, such as visible light, infrared radiation and microwaves. New technology can allow for improved measurements.

8. For Earth observations, how should balance be achieved between new capability and continuity and what is the role of cross calibration in achieving continuous data records?

   This is a good question and cannot be answered simply. Ultimately it is a question of priorities about which observations are most useful and cost effective for weather and climate and therefore must be sustained over the long term. Not all new capabilities must or can be sustained. So the nation must prioritize and plan strategically. There have been studies that recommend key benchmark observations that must be sustained.

Cross calibration is very important as observing systems are replaced by new systems. Observations with intrinsically minimum biases should be considered wherever possible, because these require a minimum of cross calibration. These are sometimes called "benchmark" observations. Radio occultation observations are one excellent example for atmospheric soundings, and continuing these observations into the future was a key Decadal Survey recommendation to NOAA.

9. In achieving effective space measurements, when is it critical that instruments be flown on the same space craft versus on separate satellites such as has happened with the A-train associated with EOS Aqua?

The answer to this question depends on the observations being made and their purpose. For <u>process studies</u> it is often highly desirable to have multiple instruments measuring the same part of the Earth system at the same time. For other purposes like weather prediction and climate monitoring this is not necessary. Other factors can be very important, such as quasi-uniform global coverage in space and time (for example, to avoid diurnal biases and aliasing getting into the record).

10. Instead of VIIRS, NPOESS could have included copies of the EOS MODIS instrument, but the group that built MODIS had ceased to exist when time came to build VIIRS. More than once, the United States seems to have lost its ability to build sophisticated remote sensing instruments and satellites. What lessons can we learn from this, and what does this say about U.S. industrial policy?

This is another complex and important question! In general, NOAA should not be relying on new technologies for its operational missions, and so a copy (possibly improved incrementally and conservatively) of MODIS would likely have been a better choice for NPOESS than VIIRS, which was a new and risky technological challenge. The solution comes down again to long-term strategic planning. Since we knew a MODIS-like capability was important for NOAA's operational suite, we could have planned for additional versions of MODIS to be built for NOAA and the capability would not have been lost. Again long-term planning is important! Industry would benefit from long-range plans because they can maintain or shift teams of engineers and managers to new systems that are in the plans.

Traditionally, NASA has developed NOAA's operational satellites, instruments, and ground systems with NOAA funds. Following launch, operations were transferred to NOAA. NPOESS development has proceeded with a different tri-agency structure that has not worked well in controlling costs and maintaining program content and schedule. NASA's NPOESS Preparatory Program was planned as a means to test the VIIRS instrument and other new capabilities, but so far, this has not worked either and data continuity with the EOS Aqua satellite is in jeopardy.

11. Looking ahead, how can the common interests of NASA Earth science and NOAA's satellite systems be effectively brought to bear to help control costs while increasing the robustness and capability of the operational satellite systems?

    Elements of a solution should include:

    a. *Long-term national plans updated on a regular basis*
    b. *Clear definition of agency mission responsibilities (e.g. for continuity of observations). One suggestion is to make NASA the U.S. civilian space agency to design, build and launch all civilian Earth satellites while NOAA focuses on processing the data and using them in models and in other ways to produce predictions and information products.*
    c. *A rigorous review process of proposed missions which would include non-advocate reviews by experts at the beginning of a mission (proposal stage, before it is funded) and at key points along the way, with rigorous and real cost-control mechanisms. The Decadal Survey talks about this and makes recommendations. Holding program managers responsible and being willing to stop missions that greatly exceed their original cost estimates are important ingredients of this strategy. Mechanisms for cost-control should be put into the end-to-end process.*
    d. *An improved research-to-operations process, e.g. see the NRC CONNTRO report and the recommendation to establish an Interagency Transition Office (ITO).*
    e. *Alternative ways of obtaining the required observations should be considered, rather than the large-platform paradigm that NASA and NOAA have followed. Smaller missions using one or multiple microsatellites in a constellation, and managed and built by entities such as universities (e.g. University of Colorado LASP-Laboratory for Atmospheric and Space Physics) should be considered. A national RFP*

process asking for proposals for a fixed price to meet observational requirements should be considered for some observations.

The University Corporation for Atmospheric Research (UCAR) includes as members many US universities and was originally formed to create the National Center for Atmospheric Research (NCAR).

12. What roles does UCAR play beyond NCAR, and are there plans to take on more activities? We play a number of significant roles beyond NCAR, though NCAR is our highest priority. Some of the most significant UCAR programs other than NCAR include the Constellation Observing System for Meteorology, Ionosphere and Climate (COSMIC), a constellation of six micro-satellites that use the radio occultation method to obtain accurate and precise atmospheric soundings in all weather; Unidata, a system that delivers weather data to over 150 universities, and COMET, a distance-learning program that serves the National Weather Service. For descriptions and access to all UCAR programs please see www.ucar.edu.

13. Given the accomplishments of UCAR and NCAR, would you recommend the creation of similar structures in oceanography, hydrology or terrestrial ecology?

UCAR and NCAR have been very successful and other communities might consider this relationship as a model. It is up to the communities to decide.

NSF sponsored the creation of UCAR and NCAR.

14. Today, what proportion of UCAR and NCAR funding comes from the different federal agencies, from non-federal governmental organizations, and from private philanthropy?

The UCAR column includes NCAR plus all other UCAR program. The NCAR column includes only NCAR. These are FY08 expenditures:

	UCAR	NCAR
NSF	58.75 %	68%
NASA	7.5	6%
NOAA	12.1	2%
DoD	6.1	6%
FAA	3.3	4%
DOE	1.8	2%
Foreign	3.2	3%
Commercial	2.9	4%
Univ	3.0	3%
Other	1.4	1%

(Totals may not equal exactly 100% because of rounding.)

15. Should NSF continue its dominant role with respect to NCAR, or should any other agencies be considered as taking primary responsibility for NCAR or for any new similar entities?

The continued core support of NCAR by the NSF is extremely important. This ongoing support allows NCAR to concentrate on very large problems, such as climate modeling, that would be difficult to do with small groups and without stable long-term funding. However, NCAR does important work with support from other agencies, such as the COSMIC and COMET programs. These programs often leverage the support of NSF, as well as the other supporting agencies.

16. What institutions in the U.S. play a role similar to that of NCAR for other areas of Earth science, such as oceanography, hydrology, and terrestrial ecosystems?

There are really no other institutions like UCAR-NCAR. NCAR is a national laboratory run by the universities, not a federal agency. But NCAR is an NSF FFRDC, so it has a special relationship to the NSF. NOAA laboratories and NASA centers play roles somewhat similar to NCAR's role, but they are managed and operated by federal agencies and are hence more mission oriented than NCAR. And one of the key aspects of NCAR's mission is to both serve and lead the universities.

QUESTIONS FOR THE RECORD, from Mr. Aderholt, Hearing: March 19, 10:00a.m.

Hearing: Climate Satellite Requirements and NASA and NOAA Programs

Witness: Dr. Anthes

Question: Despite their claims to the contrary, scientists do not yet sufficiently understand how the climate works or how it will respond to additional greenhouse gasses that are emitted into the atmosphere. Yet, this lack of understanding forms the scientific basis for climate models. There is evidence that climate models have over-estimated the warming of the planet over the past couple of decades. I am told that there is some evidence that the current climate models predict more global warming than has been seen over the past couple of decades. If this is true, can you help me understand the mismatch between the observations and the model projections?

Response by Richard A. Anthes: Thanks very much for an excellent question. Scientists do know enough about the climate system and radiation theory to understand the greenhouse effect on climate, through which certain atmospheric gases such as carbon dioxide keep a planet much warmer than it would be without these gases. Differing amounts of greenhouse gases are the primary reason why Venus, a planet with an amount of carbon dioxide much greater than Earth's, is much hotter than Earth; while Mars, a planet with much less carbon dioxide than Earth, is much colder.

I do not know of any scientific evidence that climate models in general have overestimated the warming of Earth over the past couple of decades. In fact, the world's best, and independent climate models reproduce the mean temperature of Earth very well—please see Figure 1 below.

The greenhouse gas theory is very well understood, and increasing the carbon dioxide content of our atmosphere is almost certainly going to increase the global mean temperature by close to the amount the models predict—for a given carbon dioxide emissions scenario. There are still uncertainties, however, mostly in how the emissions will actually evolve and how fast the carbon dioxide increases. Recent measurements have shown that the carbon dioxide is increasing even faster than the "worst case" assumed by the IPCC. And, while global warming is a near certainty, there are significant uncertainties in how this average warming will affect the weather patterns and over smaller regions such as states where it really matters to people. While the local details are uncertain, there is plenty to be concerned about, as governors in the western states are acutely aware with respect to water supplies in the future.

And a final point—models are just as likely to be under-predicting the amount of future warming as they are to be over-predicting it. In fact, the melting of the Arctic Ocean sea ice in summer is observed to be occurring at a faster rate than any of the models! Please see Figure 2 below.

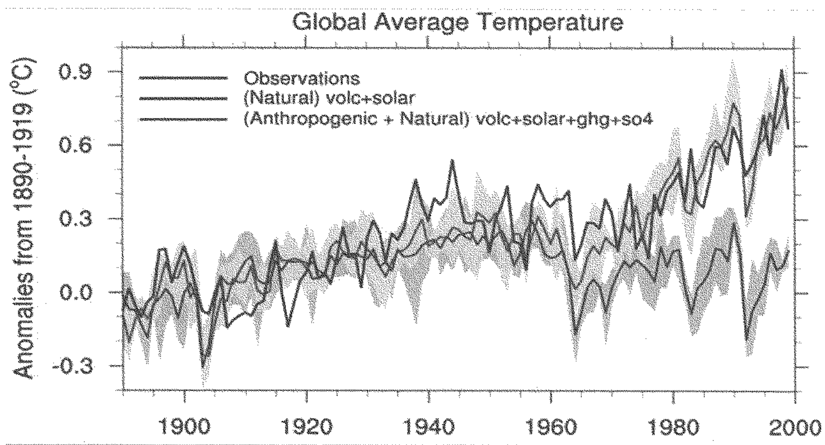

Figure 1: Observed global average temperatures from 1880 to 2000 (black line) and the range of model predictions using only natural forcing (volcanoes and solar variability—blue line and shading) and natural plus human forcing (greenhouse gases and aerosols---red curve and shading). This shows that when human and natural forcings are included in the models, they reproduce the observed global mean temperature very well. When human forcing is omitted, the models do not show the observed warming since about 1960.

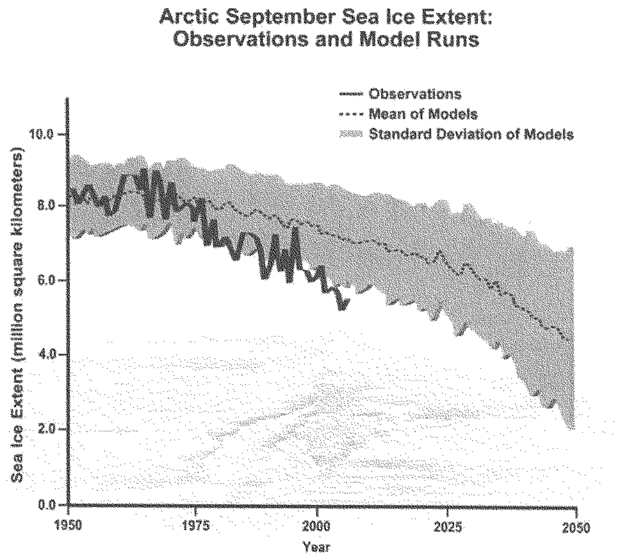

Figure 2: Observed sea ice extent in late summer in the Arctic Ocean (red curve) and the mean and range of many climate models (dotted blue line and blue shading). This shows that even the most "extreme" climate model underpredicts the observed rate of sea ice loss.

WITNESSES